Energy, Mines and Resources Canada
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# SMALL-SCALE METHANOL PRODUCTION AND ITS POTENTIAL APPLICATION IN N.W.T. COMMUNITIES

Canada

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The opinions and recommendations in this report are those of the consultant and not necessarily of Energy, Mines and Resources Canada.

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## EXECUTIVE SUMMARY

The purpose of this study has been to investigate, on a preliminary basis, the technical and economic feasibility of producing methanol from local natural gas resources in NWT. The prospective feasibility of methanol use in NWT communities is based on the availability of indigenous gas reserves in the NWT and on the availability of adjacent, as well as remote, communities to fully utilize the methanol produced. The sale of methanol outside NWT would not be economically feasible. The market for methanol is related to its ability to substitute for existing fuels, particularly highly refined P-50 furnace oil for space heating and diesel fuel for electricity generation. The transportation, handling and utilization of the methanol has also been investigated.

This four-week study has not involved any field investigations. It is based on a review of published sources, in-house studies and documentation within Stone & Webster and personal contacts with other organizations and individuals involved with development of methanol as a fuel. A previous Stone & Webster Report "Economic and Technical Feasibility Study of Distributing Natural Gas and/or Liquid Fuels to NWT Communities," March 1984,[1] identified various local supplies of shut-in reserves particularly at Parsons Lake, Taglu, and Titalik in the Mackenzie Delta, and Cameron Hills and Zama, south of Great Slave Lake. The study considered current methane production technologies and their potential application in NWT; transportation and handling of methanol; methanol as a substitute fuel for power generation, space heating and transportation, the emphasis being on the first two of these; safety and environmental factors; and overall economic feasibility of introducing methanol.

The principal findings are:

1. Small-scale methanol production by existing standard technology is technically feasible in NWT. However, economic assessments conducted herein conclusively rule out application of downsized standard production technology because capital requirements would be excessively high and community conversion potential too inherently uncertain to justify large, risky capital expenditures.

2. Recently published claims for non-standard, mini-scale production of methanol in portable plants cannot be substantiated at this time. As of March 1985 no such plants have been built and no engineering designs upon which accurate capital cost estimates could be based are available. The available cost data is, therefore, conceptual and must be considered at this time extremely uncertain.

3. However, the technical feasibility of methanol systems offers, at least in theory, a practical alternative to continued reliance on refined petroleum products. If one accepts, for the moment, vendor claims of cost feasibility for the mini-scale plants, the economic analyses portray favourable economic conditions. The sales forecasts for methanol in the selected communities are realistically attainable given financial support for a pilot project or limited conversion program.

[1] See page vi

4. However, it is recommended that no pilot or demonstration projects should be seriously considered until adequate cost research yields reasonably precise capital, and Operating and Maintenance cost estimates.

5. Consideration of methanol as partial or total substitution for existing fuels in heat and power generation has indicated no obvious technical constraints and the report discusses some appropriate demonstration programs.

6. The results of widespread trials of methanol as prime or supplementary blending fuel in motor gasolines, although promising, indicate that this form of substitution is not recommended for application in NWT at the present time.

7. Safety and health hazards and environmental factors resulting from methanol substitution have been investigated and again appear to present no serious constraints.

8. A detailed review of existing legislation applicable in NWT should be performed before the general introduction of methanol as a fuel is permitted.

The prime recommendation is that additional research be focussed on developing a technical and economic data base for mini-sized (30-50 t/day), self-contained methanol plants in order to solidify capital and O&M estimates. This offers the best approach, at present, to the preponderance of shut-in natural gas in NWT and the formulation of lower cost alternatives to community energy cost burdens in the long run.

[1] Prepared for the Government of the Northwest Territories. Funded jointly by the Government of the Northwest Territories and Energy, Mines and Resources Canada.

# PRODUCTION À PETITE ÉCHELLE ET UTILISATION POSSIBLE DU MÉTHANOL DANS LES COLLECTIVITÉS DES TERRITOIRES DU NORD-OUEST

## Résumé

Dans l'étude, on a déterminé de façon préliminaire la faisabilité technique et économique de la production de méthanol à partir des ressources locales de gaz naturel des T.N.-O. L'éventuelle faisabilité de l'utilisation du méthanol dans les agglomérations des T.N.-O. est fondée sur la disponibilité des réserves de gaz de la région et sur l'utilisation maximale du méthanol produit par les agglomérations situées à proximité et à une certaine distance des gisements. Il ne serait pas rentable de vendre le méthanol à l'extérieur des Territoires. L'ampleur du marché du méthanol est fonction de sa capacité de remplacer les combustibles existants, plus particulièrement le mazout P-50 hautement raffiné qui sert au chauffage des locaux et le diesel utilisé pour la production d'électricité. Les questions de transport, de manutention et d'utilisation du méthanol ont également été étudiées.

Aucune enquête sur le terrain n'a été effectuée dans le cadre de l'étude échelonnée sur quatre semaines et fondée sur une revue de documents déjà publiés, d'études internes, de la documentation de la firme Stone & Webster et sur des entretiens avec d'autres organismes et particuliers s'occupant de la mise en valeur du méthanol comme combustible. Un rapport de la Stone & Webster intitulé "Economic and Technical Feasibility Study of Distributing Natural Gas and/or Liquid Fuels to NWT Communities"(1), datée de mars 1984, a déterminé l'existence d'approvisionnements locaux non utilisés, plus particulièrement dans les régions de Parsons Lake, de Taglu et de Titalik, dans le delta du MacKenzie, et de Cameron Hills et de Zama, au sud du Grand Lac des Esclaves. Dans le cadre de l'étude, on a analysé les techniques actuelles de production du méthanol et leurs applications possibles dans les T.N.-O.; le transport et la manutention du méthanol; l'utilisation du méthanol comme substitut pour la production d'électricité et le chauffage des locaux ainsi que comme carburant de transport, l'accent ayant été mis sur les deux premiers éléments à l'étude; les questions de sécurité et d'environnement et la faisabilité économique globale de son utilisation.

Voici un bilan des principales conclusions de l'étude.

1. Il est techniquement possible de produire du méthanol à petite échelle, conformément aux techniques normalisées actuelles dans les T.N.O. Toutefois, compte tenu des évaluations économiques effectuées durant l'étude, on a écarté de façon concluante la possibilité d'utiliser les techniques réduites normalisées de production car les

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(1) Rapport effectué pour le gouvernement des Territoires du Nord-Ouest et subventionné conjointement par le gouvernement des T.N.-O. et par Énergie, Mines et Ressources Canada.

besoins en capitaux seraient extrêmement élevés et le potentiel de conversion pour les collectivités beaucoup trop incertain pour justifier des mises de fonds considérables et risquées.

2. Les affirmations récentes selon lesquelles il est possible de produire du méthanol à petite échelle dans des usines mobiles en utilisant des techniques qui ne sont pas normalisées ne peuvent être confirmées pour le moment. Au mois de mars 1985, aucune usine du genre avait été construite et il n'existe aucun plan sur lequel fonder des estimations précises des coûts en capital. Les données disponibles sur les coûts sont donc théoriques et, par conséquent, considérées comme extrêmement incertaines pour l'instant.

3. Cependant, la faisabilité technique de la production de méthanol offre, du moins théoriquement, une solution pratique à la dépendance continue envers les produits pétroliers raffinés. Si l'on accepte, pour l'instant, les revendications des vendeurs concernant la faisabilité des coûts des usines de petite envergure, les analyses économiques révèlent que les conditions économiques sont favorables. Les prévisions de vente de méthanol dans les agglomérations choisies seraient réalistes sous réserve de l'appui, par le gouvernement des T.N.-O. d'un projet-pilote ou d'un programme de conversion limité.

4. On recommande toutefois de ne pas envisager sérieusement de projet-pilote ni de démonstration tant qu'on n'aura pas obtenu des prévisions raisonnablement précises des coûts en capital, de fonctionnement et d'entretien.

5. Selon l'étude, il n'y a aucune contrainte technique à l'utilisation du méthanol comme substitut partiel ou total des combustibles existants pour le chauffage et la production d'électricité; le rapport traite de quelques programmes de démonstration pertinents.

6. Compte tenu des nombreuses mises à l'essai, l'utilisation du méthanol comme composante principale ou secondaire des mélanges de carburants automobiles, bien qu'elle soit premetteuse, n'est pas recommandée pour l'instant dans les T.N.-O.

7. Les risques pour la sécurité, la santé et l'environnement de la substitution du méthanol aux autres combustibles ont été étudiés et, une fois de plus, l'utilisation de cette substance ne semble présenter aucune difficulté majeure.

8. Il faut procéder à une revue détaillée des lois s'appliquant aux T.N.-O. avant de permettre l'utilisation générale du méthanol comme combustible.

La principale recommandation du rapport est d'axer les recherches additionnelles sur la constitution d'une base de données techniques et économiques concernant les usines indépendantes de production de méthanol à petite échelle (30-50 t/j) afin de préciser davantage les estimations des coûts en capital et de fonctionnement et d'entretien. À l'heure actuelle il s'agit de la meilleure façon de faire face aux volumes de gaz naturel non utilisés dans les T.N.-O. et de trouver des solutions à long terme moins coûteuses au problème des coûts de l'énergie pour les agglomérations de la région.

Cette étude a été effectuée par Stone & Webster Canada Ltd. pour le Programme de démonstration dans les collectivités éloignées d'Énergie, Mines et Ressources Canada.

## COMPARAISON DU COÛT AU DÉTAIL DES COMBUSTIBLES

| Technique | 1re année (1986) | | | 10e année (1995) | | |
|---|---|---|---|---|---|---|
| | Méthanol | | Pétrole | Méthanol | | Pétrole |
| Agglomération | $/L | Équiv. de pétrole | $/L | $/L | Équiv. de pétrole | $/L |
| Normalisée | | | | | | |
| - Yellowknife | .321 | .697 | .391 | .165 | .358 | .455 |
| - Inuvik | .274 | .595 | .401 | .22 | .477 | .480 |
| - Éloignées | .273 | .592 | .501 | .22 | .477 | .600 |
| Non Normalisée | | | | | | |
| - Yellowknife | .186 | .404 | .391 | .119 | .258 | .455 |
| - Inuvik | .190 | .412 | .401 | .118 | .257 | .480 |
| - Éloignées | .191 | .414 | .501 | .158 | .343 | .600 |

## 1.0 INTRODUCTION

The purpose of this study has been to investigate the technical and economic feasibility of producing methanol from natural gas feedstocks on a scale appropriate to population distributions and community sizes in selected areas of NWT, which would provide a market for the methanol by substituting it for existing fuels, particularly liquid petroleum products, and to investigate the available technologies for transporting, handling and using the methanol appropriate to this substitution.

Secondary objectives of the study have included consideration of demonstration schemes for methanol production; substitution of fuel oils by methanol in the domestic, commercial and industrial sectors; and the use of methanol to supplement current transportation fuels either by blending or direct substitution.

The four week study has not involved any field investigations. It has been, as required by the contract, a review of the existing state-of-the-art of methanol technology and its attendant economics as available in published sources, in-house studies and documentation within Stone & Webster, supplemented by personal contacts with a number of other organizations and individuals to bring the work up to date. Much of the basic data on energy consumption, natural gas reviews and current energy economics for NWT are taken from the previous Stone & Webster Report "Economic and Technical Feasibility Study of Distributing Natural Gas and/or Liquid Fuels to NWT Communities," March 1984.*

The economic analysis of the methanol case is an extension to the previous work.

### 1.1 Background

During recent years the production of methanol from synthesis gases (mixture of carbon monoxide, carbon dioxide and hydrogen) has become a thoroughly proven, widely employed technology for which several proprietary processes are available and several more are under development. Industrial experience has also shown that, in general, the reforming of natural gas by catalytic reaction with steam has been the most economically favourable route to synthesis gases, although other fuel feedstocks including refinery and oil gases, coal, wood and other fuels are also technically feasible sources.

At the present time, Canada has three world scale methanol plants, two located in Alberta and one in British Columbia, having a combined annual production capacity of 1,750,000 metric

* Prepared for the Government of the Northwest Territories (GNWT). Funded jointly by GNWT and Energy, Mines and Resources Canada.

tons. The plants produce chemical grade methanol which is used in other processes producing a variety of chemicals. In fact, most of the methanol produced worldwide is used for these purposes although during the past decade there have been many suggestions that methanol provides a convenient replacement for liquid petroleum fuels or, at least, a useful supplement for blending with these fuels and these assertions are increasing. A large number of programs are already in progress to demonstrate the substitution of fuel oils by methanol in spark ignition engines, stationary and mobile diesel engines, gas turbines, furnaces, boilers and stoves. Canada has played a leading role in these developments.

A related technology is the production of methyl fuels by somewhat different process technology, the product containing up to 25 per cent of higher alcohols. These products offer some advantages over methanol for blending with gasolines, being less susceptible to phase separation and vapour lock problems. However, their production is attended by lower specific yields and higher costs, and this technology will not be considered further as part of the present work.

The Northwest Territories, comprising more than one third of the Canadian landmass, straddles three potential hydrocarbon producing areas. They are:

i) Western Canada Sedimentary Basin
ii) Arctic Islands
iii) Hudson Bay

The first of these includes the entire Mackenzie River Valley and delta areas in which substantial natural gas reserves have been proven to the south at Cameron Hills on the Alberta/NWT border and, in the north, in the Mackenzie Delta and Beaufort Sea areas. Very large mainland reserves have been proven in the area around Inuvik and Tuktoyaktuk (Tuk). Even larger reserves have been discovered in the Arctic Islands region. The Hudson Bay area has, so far, failed to provide any indications of major natural gas resources.

The communities adjacent to natural gas reserves are therefore:

i) Fort Smith region around Great Slave Lake and in close proximity to the Cameron Hills gasfields.

ii) Inuvik region on the Mackenzie Delta and close to the Parsons Lake, Titalik gasfields.

iii) Centre Arctic region, which could be supplied by methanol produced at Parsons Lake or at the Melville Sound areas.

The communities on the Hudson Bay, Foxe Basin areas have no adjacent natural gasfields. The broad categories of communities investigated in this study are, accordingly, the three areas enumerated above.

This study forms a part of the Remote Community Demonstration Program which is designed to encourage alternatives to oil, and energy conservation by remote communities and agencies responsible for their energy supply.

## 2.0 COMMUNITY FACTORS

### Introduction

This section analyses essential infrastructure data for NWT communities, including current energy consumption patterns, in order to provide a basis for determining appropriate scales of methanol production and methanol substitution possibilities.

### 2.1 Sizes, Distributions and Aggregations of Communities

Census data for 1981 and a map of NWT were used to ascertain sizes, distribution and aggregation of communities. The total population is small (less than 46,000), and generally scattered in widely dispersed communities which fall into the following classes-

| Size | No. of Communities |
|---|---|
| <1000 | >40 |
| 1001 -- 2500 | 6 |
| 2501 -- 5000 | 2 |
| 5001 -- 10,000 | 1 (Yellowknife) |

The major concentrations of population occur in the Fort Smith, Inuvik and Keewatin Census Regions.

### 2.2 Transportation Modes

Transportation of methanol from the production plant to the user involves two separate components. First, transportation from the plant fieldgate to the community and second, distribution to individual customers in the community. Transportation modes to Great Slave Lake and Mackenzie Delta communities are by established modes and have been priced out by adapting data developed for the Economic and Technical Feasibility Study of Distributing Natural Gas and/or Liquid Fuels to NWT Communities. (1984) Data for ship delivery to the more remote NWT communities was not available, but should parallel barge rates. Distribution costs would be expected to be somewhat higher than for Mackenzie Delta communities.

Some key points relative to transportation modes are:

- Rail transport: Zama Lake to Hay River. Propane is normally shipped by rail from Edmonton to Hay River. Cost for rail shipment assumes siding available at Zama Lake.

- Truck transport: used if only mode available or as an alternate to barge or rail, roads not available from Norman Wells, and road between Tuktoyaktuk and Inuvik only open late June through March.

- Barge transport: used where applicable. Barge season June through September.

- Propane and heating oil are presently transported to the listed communities by barge.

- Distribution costs-used NWT study data. Margin for propane delivery in Yellowknife and the northern communities.

Using the cost elements derived from the NWT study unit costs applicable to methanol were derived. These unit costs are:

| Mode | $ Per Litre Per km |
|---|---|
| Rail | $0.000030 |
| Barge | $0.000087 |
| Truck | $0.000126 |

| Distribution | $ Per Litre |
|---|---|
| Great Slave Lake | $0.074 |
| Mackenzie Delta | $0.093 |

Total unit transportation costs by community are summarized in Table 2.1. Costs for other communities may be estimated by using the unit costs from the above table.

2.3 Fuel Consumption

2.3.1 Statistics Canada data was used to identify potential users. Major users of fossil fuels include electrical generators; industrial, commercial and institutional installations; district heating facilities; and residences.

2.3.2 Electrical Power

Electrical generation in NWT is primarily undertaken by the Northern Canada Power Commission, with smaller amounts being produced by Northlands Utilities (NWT) Limited, Canada Tungsten Mining Corp. Ltd., Cominco Ltd., and Echo Bay Mines Ltd.,

2.3.2.1 The breakdown of electrical generation by capacity is as follows:

| | |
|---|---|
| Utility Companies | 46 MW - Hydro<br>116 MW - Internal Combustion |
| Industrial Companies | 3.4 MW - Hydro<br>23.8 MW - Internal Combustion |

2.3.2.2 The electrical power production split is approximately as follows:

a) Electric Utilities
60 per cent hydro/40 per cent fossil

b) Industry
40 per cent hydro/60 per cent fossil

2.3.2.3 The production split between utilities and industry is 93 per cent utilities/7 percent industry, with total production in 1982 being approximately 475,000 MWh.

2.3.2.4 Electrical power interchange between NWT and other provinces is non-existent and furthermore, electrical power transmission is very localized, the total transmission circuit length being only 749 km in 1982.

2.3.2.5 Power generation facilities in NWT are therefore widely spread out with no interconnections. Facilities are base loaded, with multiple generators at each location for reliability and load following capability.

2.3.2.6 All internal combustion engines are diesel generators. The total number of installations listed in 1983 was 56, with a total of 242 units. Fig. 2.1 and Index shows the locations of diesel electric generating plants in NWT.

2.3.2.7 Major concentrations of diesel generator sites are the three areas as follows:

a) Round Great Slave Lake, with 13 locations, and 49 diesel generator sets, totalling 50,258 kW.

b) Down the Mackenzie River from Wrigley to Tuktoyaktuk, with 11 locations and 36 diesel generator sets, totalling 25,722 kW.

c) On Hudson Bay from Eskimo Point to Baker Lake, with 5 locations and 18 diesel generator sets, totalling 8,928 kW.

Elsewhere the locations are more scattered, with no particular concentration evident.

Table 2.2 summarizes the locations, quantities, and capacities of the generator sets.

2.3.2.8 Steam turbine generators and gas turbine generators are not used in NWT. Hot water generators are, however, in use in Inuvik and Frobisher Bay for district heating.

2.3.3 Industrial Use

2.3.3.1 In NWT, the vast majority of industrial fuel usage is accounted for by the mining industry which, by value in 1980, accounted for over 95 per cent of energy consumed by industry and manufacturing.

2.3.3.2 The major mining facilities are located at Pine Point, Tungsten, the Lupin Mine about 400 km NE of Yellowknife, the Cominco mine just outside of Yellowknife and the Polaris mine on Little Cornwallis Island.

2.3.4 Commercial, Industrial and Residential Use

2.3.4.1 These three categories, being population derived, are obviously interlinked with one another, the greatest potential existing where the greatest populations are to be found.

2.3.4.2 As previously indicated in Section 2.1, 1981 census data indicates that over 50 per cent of the population is gathered in three areas, these being Great Slave Lake, the Mackenzie River, and the west shore of Hudson Bay. The Hudson Bay area is too remote from natural gas sources and is therefore excluded from further consideration.

2.3.4.3 The population breakdown for the two remaining areas is as follows:

a) Great Slave Lake Area

| Town | Population | Number of Occupied Dwellings |
|---|---|---|
| Yellowknife | 9,500 | 3,250 |
| Rae-Edzo | 1,380 | 240 |
| Fort Providence | 800 | 130 |
| Hay River | 2,400 | 930 |
| Pine Point | 1,860 | 530 |
| Fort Resolution | 480 | 120 |
| Fort Smith | 2,300 | 670 |
| Snowdrift | 250 | 50 |
| TOTAL | 19,470 | 5,920 |

b) Mackenzie River Area

| Town | Population | Number of Occupied Dwellings |
|---|---|---|
| Inuvik | 3,150 | 950 |
| Aklavik | 720 | 170 |
| Tuktoyaktuk | 770 | 140 |
| Arctic Red River | 120 | 25 |
| Fort McPherson | 630 | 130 |
| Fort Good Hope | 450 | 100 |
| Norman Wells | 290 | 70 |
| Wrigley | 140 | 30 |
| Fort Simpson | 980 | 260 |
| Jean Marie River | 70 | 10 |
| Fort Providence | 510 | 130 |
| TOTAL | 8,250 | 2,150 |

2.3.4.4 As Tuktoyaktuk and Inuvik are located close to major gas fields, it is logical to consider this area as a potential central methanol manufacturing and distribution centre, servicing the Central Arctic area. This area contains the following communities:

| Town | Population | Number of Occupied Dwellings |
|---|---|---|
| Bathurst Inlet | 20 | 5 |
| Bay Chimo | 60 | 10 |
| Cambridge Bay | 820 | 210 |
| Coppermine | 810 | 180 |
| Gjoa Haven | 520 | 90 |
| Holman | 300 | 65 |
| Spence Bay | 430 | 85 |
| Paulatuk | 100 | 20 |
| Sachs Harbour | 150 | 30 |
| TOTAL | 3,205 | 695 |

2.3.5 Combined Totals

2.3.5.1 The combination of population, residences, and diesel generator capacities with the specific locations is shown in Table 2.2.

2.3.5.2 The grand totals shown represent the following percentages of the relative totals for the Northwest Territories.

| | |
|---|---|
| Population | 25 per cent |
| No. of Residences | 24 per cent |
| Installed Diesel kW | 27 per cent |

2.3.5.3 The methods of deriving the energy consumed by the above were as follows:

a) Diesel Generators
The total fossil energy (diesel and heavy fuel oil) consumed by the utility was prorated on the basis of installed power in the areas under consideration.

b) District Heating in Inuvik
With a winter peak of 84.4GJ/h, and a summer load of 21.1GJ/h, a mean annual load of 63.3GJ/h was assumed.

c) Commercial and Institutional
Using information derived from "Economic and Technical Feasibility Study of Distributing Natural Gas and/or Liquid Fuels to NWT Communities" prepared by SWCL in March 1984, energy consumptions on a population basis were derived and used to calculate total energy consumed.

d) Residential
As above, domestic heating requirements on a per residence basis were taken from the report and used to calculate total energy consumed.

e) The total energy for all the above was converted to methanol equivalent terms by assuming that each tonne of methanol is equivalent to 22.69 GJ. See Table 2.3.

2.3.6 Energy Costs

Energy costs for selected fuels are given in Table 2.4, Historical Fuel Price Comparison.

## 2.4 Methanol Conversion Potential

Methanol conversion potential has been assessed on an order of magnitude (O/M) basis based on the detailed market evaluations and computer analyses conducted in Stone & Webster's prior studies in NWT, as well as the inherent technical constraints which attend methanol utilization. In the prior study published in March 1984, Stone & Webster evaluated natural gas (liquids) substitution prospects for communities in the Great Slave Lake area and the Mackenzie Delta communities. The economic and technical feasibility of gas (liquids) for primary NWT communities reflected likely substitution prospects, particularly where natural gas for oil space heating and various electric loads would generate sufficient savings to cost justify the required capital expenditures borne by consumers for the sake of conversion.

Preliminary methanol substation prospects suggested in this analysis reflect the limited applicability of methanol for community energy requirements. In the residential sector, methanol could be used for a variety of end-uses but associated penetrations are limited exclusively to oil space heating requirements. No substitution of methanol for less expensive wood, electric space heating or electric water heating considered.

Commercial substitution potential is also related exclusively to space heating requirements. As in the prior study, industrial substitution prospects may be broken down into power applications and other industrial activity. Based on the projected natural gas volumetric requirements shown in Exhibit 18 of Stone & Webster's Economic and Technical Feasibility Study, methanol substitution is estimated to equal 40% of the projected annual fossil-fired electric production capability. A 40/60 per cent methanol-diesel fuel mix would not necessitate major retrofit requirements for the electric companies, and would not cause noteworthy operational complexities. Although nozzles and injection systems would be modified at relatively low cost, there would be no other significant capital or O&M cost penalty, or adverse effect on net operating capability. Finally, "other" industrial substitution potential has been somewhat conservatively estimated at 10 per cent of natural gas sales on a heating value equivalent basis.

Refined petroleum product prices make nearly all NWT communities potential candidates for methanol substitution. Existing territorial and federal government policies result in substantial subsidies for fuels used by residential consumers, particularly government employees. Sales projections assumed in the prior study and presented again with adjustments herein reflect the social opportunity cost of petroleum products, and are therefore predicted on rational consumers making logical decisions about alternate fuels with respect to economic selfinterest. In actuality, the conversion potential in the price and policy sensitive residential sector in each community would be greatly impacted by government edict.

Based on the standard technology at 300 metric tons per day production levels, community conversion potential in the first year of methanol availability can be summarized as follows:

| Community | Standard Technology (Thousands of Litres) |
|---|---|
| Yellowknife | |
| Residential | 14,392 |
| Commercial | 19,907 |
| Power | 4,928 |
| Other Industrial | 2,039 |
| Total | 41,266 |
| Inuvik/Mackenzie Delta | |
| Residential | 8,385 |
| Commercial | 6,987 |
| Power | 101 |
| Other Industrial | 6,594 |
| Total | 22,067 |
| Remote | |
| Residential | 1,364 |
| Commercial | 1,774 |
| Power/Ind. | 47 |
| Total | 3,185 |

These projected sales levels must be considered as preliminary, and could vary dramatically. Residential and commercial volumes, in particular, would invariably be lower, as methanol sales potential has been calculated under full oil displacement conditions.

## 2.5 Potential Supply Sources

Several gas supply sources in Alberta, British Columbia, Yukon and Northwest Territories were investigated to identify the gas sources which have adequate reserves (minimum of 20 year supply) and appear to be economically viable due to nearness to the respective communities. The following table summarizes reserves information on possible sources:

Table 2.5

GAS RESERVES BY SOURCE

| | BCF (TJ) | |
|---|---|---|
| | Proven[1] | Probable[2] |
| **Alberta** | | |
| Zama Lake | - - - - - - - - - (3) - - - - - - - - | |
| Indian Cabins | 6.6 (6,963) | - |
| **Northwest Territories** | | |
| Cameron Hills | 22.9 (24,160) | 26.0 (27,430) |
| Kakisa Lake | 10.7 (11,289) | 2.0 (2,110) |
| Hay River | - | 0.1 (106) |
| Parsons Lake | 1240 (1,308,200) | - |
| Titalik | 51 (53,805) | - |
| Reindeer | 8 (8,440) | - |
| Ya-Ya | 28 (29,540) | - |

1 Data recorded from wells actually drilled.

2 Reserves which may be discovered by the further drilling of neighbouring lands.

3 Data not available but reserves are adequate to supply the Great Slave Lake communities.

Zama Lake, Alberta is the closest natural gas supply source with adequate reserves to meet the long term requirements of the southern communities.

The only other source of natural gas with reserves adequate to serve the southern communities is Kotaneelee, Yukon, but this source is farther away than Zama Lake. Cameron Hills, NWT appears to be a good local source of natural gas for the southern communities but its reserves are presently inadequate for pipeline systems. It could be considered for small scale methanol production plans. Drilling and seismic work is continuing in this area and more gas may be found. Another possible source of gas, but again not of adequate capacity to supply all the communities, is the area to the east and west of Kakisa Lake. There are a few wells south of Hay River but discoveries so far do not appear adequate for production.

In the Mackenzie Delta, gas has been discovered in the Beaufort Sea and at several sites along the northern coast. Some of the sites investigated were Taglu, Ya-Ya, Parsons Lake, Titalik and Reindeer. Parsons Lake and Titalik are the closest with adequate reserves to meet the long term needs of Inuvik, Tuktoyaktuk, Arctic Red River and Fort McPherson.

Through contact with Esso Limited at Norman Wells, Stone & Webster determined that approximately 7 million cubic feet of gas per day is now being flared but this quantity will decline to approximately 1.5 million cubic feet per day by the mid 1990's.

With the exception of Parsons Lake, the gas sources evaluated as methanol plant feedstocks do not require extensive gas conditioning.

At Parsons Lake the methanol production plant cost estimates includes $0.65 million for production-related gas treatment plant. This plant is designed to improve the quality of the gas by removing the natural gas liquids, (e.g. hexanes, pentanes, and LPG). A large portion of the liquids are extracted when the gas pressure is reduced from 24,400 kPa to 8,700 kPa. The remaining liquids are extracted as the gas goes through a gas to gas exchanger and is refrigerated by a small packaged unit. This unit is sized for a gas flow of 1582 GJ per day to provide a gas dew point of -29°C; this will prevent hydrate formation and plant freeze-up. The extracted liquids are collected in a knockout drum, vapourized, and flared because the small quantities involved make storage uneconomical. The total cost is for two parallel units to ensure a steady gas supply in the event of a failure by the primary unit.

## 2.6 Community Locations and Plant Production Capability

### 2.6.1 Target Communities for Methanol Substitution

Target NWT communities for methanol substitution are currently reliant on high priced refined petroleum products for heating requirements and electricity generation. Energy prices in almost all NWT communities are high in comparison to southern Canadian prices; exceptions include Norman Wells, an energy production centre for NWT, and Hay River and Pine Point south of Great Slave Lake where the availability of abundant wood supplies coupled with rail transported liquid fuels results in (relatively) affordable community energy costs. Other population centres in NWT rely on truck and barge transported liquid fuels. This transportation cost component accounts for a significant portion of retail fuel prices. Hence, in developing criteria to select communities potentially able to convert, the Project Team looked at the following key aspects:

- Existing Fuel Prices, particularly P-50 furnace oil, diesel fuel and electric prices.

- Availability of Alternative Fuels, particularly wood, or propane at competitive prices.

- Oil Saturation Levels, primarily for residential and commercial space heating requirements, and electric generating requirements.

- Proximity to Gas Fields, particularly Parsons, Taglu, and Titalik reserves in the Mackenzie Delta region, and Cameron Hills in the Great Slave Lake area where gas reserves are shut-in and would therefore have low values at the wellhead.

- Transportation Logistics, communities should be situated favourably such that transportation of liquids fuels is possible at least than 7 to 8 months a year.

In the Mackenzie Delta, likely communities include Inuvik and Tuktayaktu, Aklavik, Fort McPherson, and Arctic Red River. In the Great Slave Lake area likely communities could include Enterprise and Fort Resolution, Fort Smith, Fort Providence, Rae-Edzo, and Detah. To be sure, innumerable communities in NWT satisfy the principal eligibility criteria of high fuel prices, reliance on fossil fuels, and proximity to gas fields. To a limited extent, the energy usage patterns, fuel prices, and storage infrastructural requirements in the many remote communities are similar. The analyses conducted herein and presented in Section 6, assume that remote communities are homogeneous, thus no communities' specific treatment is included.

Instead, the economic and technical configurations have been formulated for three communities or groups of communities: Yellowknife; Inuvik and the surrounding Mackenzie Delta communities; and a "composite" remote community. Although this composite community has not been identified, the energy usage data and prices reflect Tuktoyaktuk values*, but have been adjusted to reflect higher fuel prices and harsher climatic conditions in the remote communities.

*In the prior Stone & Webster study, the Project Team collected data for Inuvik-Tuk, which could be readily adjusted for the purpose of this preliminary study.

Estimated transportation costs to bring methanol to the remote communities could be higher than those shown in Section 6, but the technical and economic logistics would otherwise closely parallel those envisaged for Inuvik and Yellowknife. Remote communities for methanol substitution could include:

| Central Arctic | Arctic Islands | Baffin | Keewatin |
|---|---|---|---|
| Bathurst Inlet | Resolute | Broughton Island | Chesterfield Inlet |
| Bay Chimo | Grise Fjord | Frobisher Bay | Baker Lake |
| Cambridge Bay | Arctic Bay | Lake Harbour | Rankin Inlet |
| Coppermine | Nanisivik | Igloolik | |
| Gjoa Hoven | Pond Inlet | | |
| Holman | | | |
| Spence Bay | | | |
| Paulatuk | | | |

2.6.2 Plant Production Capability

Plant capacity for standard technology, as described in Section 3, is based on a production capability of 300 metric tons per day. At a 90 per cent capacity factor or utilization rate, annual methanol production would remain constant at 124,472 million litres. Economics of scale render further plant downsizing undesirable from a unit cost standpoint. Hence, using standard technology, the 300 metric tons per day should be considered the minimum production level which must then supply the regional demand for industrial, commercial and residential energy requirements.

It is important to note that surplus production capability would probably exist given the standard 300 tons per day design. This is because the projected substitution potential in the three representative communities would be substantially less than expected conversion potential. In order to assess the economic merits of standard technology (e.g., 300 tons per day) on a preliminary basis, all plant output is presumably sold at market clearing prices without explicitly identifying the other market (sectors).

In addition to the standard technology, Stone & Webster also considered the potential feasibility of the downsized "portable" mini-methanol plants. These plants are currently in the concept stage only, and have neither been built for commercial purposes nor demonstrated for technical reasons. As a result, the technical and economic aspects of this small, non-standard plant design should be considered uncertain. They have been included primarily for sensitivity analysis.

Non-standard mini-methanol facilities could produce between 9,000 gallons (U.S.) to 12,500 gallons per day. This equates to approximately 15.542 million litres on an annual basis, or about 12,400 metric tons per year at a 90 per cent capacity factor.

Although the unitized cost of producing methanol at the plant fieldgate could be significantly higher than with standard technology, the lower capital cost and substantially lower annual production levels could represent more realistic production configurations in NWT. In this analysis, nonstandard technology is estimated to cost $5.0 million per plant, excluding O&M, compared to the standard design at an estimated cost of $85 million.

TABLE 2.1

METHANOL TRANSPORTATION COSTS
DELIVERY FROM THE METHANOL PLANT TO THE END USER

| Source/Transport Mode | Community | | | | |
|---|---|---|---|---|---|
| | Inuvik | Tuktoyaktuk | Arctic Red River | Fort McPherson | Yellowknife |
| | ($ Per Litre) | | | | |
| Norman Wells, NWT | | | | | |
| Barge | $.154 | $.164 | $.141 | $.148 | $.165 |
| Barge/Truck | | | | | .214 |
| Parsons Lake, NWT (Hans Bay) | | | | | |
| Barge | .155 | .136 | .166 | .167 | .288 |
| Barge/Truck | | | | .173 | .336 |
| Titalik, NWT | | | | | |
| Barge | .105 | .105 | .117 | .118 | .238 |
| Barge/Truck | | | | .124 | .287 |
| Zama Lake, Alberta | | | | | |
| Rail/Barge | .243 | .260 | .229 | | .099 |
| Truck/Barge | .273 | .290 | .259 | | .129 |
| Truck | | | | | .165 |
| Rail/Truck | | | | | .146 |
| Rail/Barge/Truck | | | | .236 | |
| Truck/Barge/Truck | | | | .266 | |
| Cameron Hills, NWT | | | | | |
| Truck/Barge | .245 | .262 | .231 | | .101 |
| Truck | | | | | .137 |
| Truck/Barge/Truck | | | | .238 | |

TABLE 2.2

SUMMARY OF LOCATIONS, POPULATIONS, AND INSTALLED DIESEL GENERATORS

| Region | Community | Population | No. of Occupied Dwellings | No. of Diesel Generators | Total Capacity kW |
|---|---|---|---|---|---|
| Inuvik | Inuvik | 3150 | 950 | 4 | 11,704 |
| | Aklavik | 720 | 170 | 3 | 1,730 |
| | Arctic Red River | 120 | 25 | 3 | 260 |
| | Fort McPherson | 630 | 130 | 3 | 1,432 |
| Central Arctic | Tuktoyaktuk | 770 | 140 | 3 | 1,994 |
| | Bathurst Inlet | 20 | 5 | - | - |
| | Bay Chimo | 60 | 10 | - | - |
| | Cambridge Bay | 820 | 210 | 5 | 2,616 |
| | Coppermine | 810 | 180 | 5 | 1,896 |
| | Gjoa Haven | 520 | 90 | 3 | 771 |
| | Holman | 300 | 65 | 3 | 545 |
| | Spence Bay | 430 | 85 | 4 | 1,058 |
| | Paulatuk | 100 | 20 | 3 | 361 |
| | Sachs Harbour | 150 | 30 | 3 | 808 |
| Mackenzie Valley | Fort Good Hope | 450 | 100 | 3 | 975 |
| | Norman Wells | 420 | 135 | 4 | 2,514 |
| | Fort Norman | 290 | 70 | 3 | 1,098 |
| | Wrigley | 140 | 30 | 3 | 459 |
| | Fort Simpson | 980 | 260 | 4 | 5,565 |
| | Jean Marie River | 70 | 10 | 2 | 70 |
| | Fort Providence | 510 | 130 | 3 | 1,609 |
| | Dory Point | - | - | 4 | 446 |

TABLE 2.3

METHANOL ENERGY EQUIVALENTS

| Area | Consumer | Energy Use Per Unit | No. of Units | Total Energy (TJ) | Methanol Equivalent (tonnes) |
|---|---|---|---|---|---|
| Central Arctic and Mackenzie River | Diesel Generation | 20.815 GJ per kW p.a. | 37,911 kW | 789.1 | 34,712 |
| Inuvik | District Heating | 63.3 GJ/h | 8760 hours | 554.5 | 24,392 |
| Central Arctic and Mackenzie Delta (1) | Commercial and Institutional | 0.04145 TJ per person p.a. | 5450 people | 225.9 | 9,937 |
| Mackenzie River (2) | Commercial and Institutional | 0.0385 TJ per person p.a. | 2860 people | 110.1 | 4,843 |
| Tuktoyaktuk and Central Arctic (3) | Domestic Heating | 187.5 GJ per dwelling | 835 dwellings | 156.6 | 6,889 |
| Mackenzie Delta (4) | Domestic Heating | 175.5 GJ per dwelling | 325 dwellings | 57.0 | 2,507 |
| Mackenzie River (2) | Domestic Heating | 165.0 GJ per dwelling | 735 dwellings | 121.3 | 5,536 |
| Total | | | | 2,014.5 | 88,816 |

Notes: (1) Includes Aklavik, Arctic Red River, Fort McPherson, Tuktoyaktuk, Bathurst Inlet, Bay Chimo, Cambridge Bay, Coppermine, Gjou Haven, Holman, Spence Bay, Paulatuk and Sachs Harbour.

(2) Includes Fort Good Hope, Norman Wells, Fort Norman, Wrigley, Fort Simpson, Jean Marie River, Fort Providence and Dory Point.

(3) Central Arctic includes Bathurst Inlet, Bay Chimo, Cambridge Bay, Coppermine, Gjoa Haven, Holman, Spence Bay, Paulatuk and Sachs Harbour.

(4) Includes Aklavik, Arctic Red River, and Fort McPherson.

TABLE 2.4

HISTORICAL FUEL PRICE COMPARISON
(Constant $)

| | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|
| **Yellowknife** | | | | | |
| Furnace Oil (¢/Litre)[1] | 34.8 | 40.3 | 46.6 | 45.0 | 39.1 |
| Electricity (¢/kWh) | | | | | |
| Residential[2] | 9.9 | 11.9 | 15.3 | 11.4 | 11.0 |
| General Services[3] | 10.2 | 12.3 | 15.8 | 11.8 | 11.4 |
| Wood ($/GJ)[4] | 5.6 | 5.4 | 6.6 | 5.0 | 5.1 |
| Propane (¢/Litre)[1] | 22.3 | 23.7 | 25.1 | 26.6 | 31.2 |
| **Pine Point** | | | | | |
| Furnace Oil (¢ Litre) | 26.1 | 30.2 | 34.9 | 33.7 | 29.3 |
| Electricity (¢/kWh) | | | | | |
| Residential[5] | 13.8 | 16.6 | 21.3 | 15.9 | 15.3 |
| General Service[6] | 14.0 | 16.9 | 21.8 | 16.3 | 15.7 |
| Propane (¢/Litre) | 13.0 | 13.8 | 14.6 | 15.5 | 14.8 |
| **Hay River** | | | | | |
| Furnace Oil (¢/Litre) | 34.1 | 39.5 | 45.7 | 44.1 | 38.3 |
| Electricity (¢/Litre) | | | | | |
| Residential[5] | 13.8 | 16.6 | 21.3 | 15.9 | 15.3 |
| General Service[6] | 14.0 | 16.9 | 21.8 | 16.3 | 15.7 |
| Wood ($/GJ) | 3.8 | 3.7 | 4.6 | 3.4 | 3.5 |
| Propane (¢/Litre) | 23.8 | 25.3 | 26.8 | 28.4 | 27.2 |

TABLE 2.4 (CONT'D)

HISTORICAL FUEL PRICE COMPARISON
(Constant $)

| | 1980 | 1981 | 1982 | 1983 | 1984 |
|---|---|---|---|---|---|
| **Inuvik** | | | | | |
| Furnace Oil (¢/Litre) | 33.0 | 38.2 | 44.2 | 42.7 | 37.1 |
| Electricity (¢/kWh) | | | | | |
| Residential[5] | 13.3 | 16.0 | 20.6 | 15.3 | 14.8 |
| General Service[6] | 13.7 | 16.5 | 21.2 | 15.8 | 15.3 |
| Wood ($/GJ) | 7.0 | 6.8 | 8.3 | 6.2 | 6.3 |
| Propane (¢/Litre) | 26.0 | 27.6 | 29.2 | 31.0 | 29.6 |
| **Tuktoyaktuk** | | | | | |
| Furnace Oil (¢/Litre) | 36.3 | 42.1 | 48.6 | 47.0 | 40.8 |
| Electricity (¢/kWh) | | | | | |
| Residential[5] | 15.4 | 18.5 | 23.7 | 17.7 | 17.1 |
| General Services[6] | 15.7 | 19.0 | 24.4 | 18.2 | 17.6 |
| Wood ($/GJ) | | | | | |
| Propane (¢/Litre) | 28.6 | 30.4 | 32.2 | 34.2 | 32.6 |

7

**Northwest Territories[8]**

| | |
|---|---|
| Fuels for Electrical Power Genration | |
| Diesel (¢/Litre) | 33.2 |
| Heavy Fuel Oil (¢/Litre) | 21.4 |

Notes for Table 2.4:

1. Source: Stone & Webster project team's field survey of furnace oil suppliers.

2. Unit prices reflect the average price for 1000 kWh and includes the fuel cost adjustment, and government subsidies for the first 750 kWh.

3. General Service rates reflect recovery of higher cost of service at historic levels.

4. Based on estimated average delivered cost per cord (4' cuts).

5. Based on the average price for monthly use equal to 1000 kWh including fuel and government price support.

6. General Service rates reflect recovery of higher cost of service at historic levels.

7. All above taken from Stone & Webster's 1984 study.

8. Statistics Canada, Electric Power Statistics, Volume II, 1982.

Figure 2.1 - Showing Locations of Diesel Electric Generating Plants (NWT)

INDEX TO FIG. 2.1

DIESEL GENERATORS IN NORTHWEST TERRITORIES

| Ref. No. | Plant Location | No. of Engines Per Plant | Total Capacity (kW) |
|---|---|---|---|
| 1 | Tungsten | 10 | 9,032 |
| 2 | Cominco Asenic Plant | 1 | 153 |
| 3 | Cominco C-1 Power House | 3 | 1,857 |
| 4 | Cominco Robertson Shaft | 1 | 597 |
| 5 | Lupin Mine | 13 | 13,935 |
| 6 | Aklavik | 3 | 1,730 |
| 7 | Arctic Bay | 3 | 1,024 |
| 8 | Arctic Red River | 3 | 260 |
| 9 | Baker Lake | 4 | 2,639 |
| 10 | Broughton Island | 3 | 498 |
| 11 | Cambridge Bay | 5 | 2,616 |
| 12 | Cape Dorset | 3 | 1,730 |
| 13 | Chesterfield Inlet | 3 | 715 |
| 14 | Clyde | 3 | 1,246 |
| 15 | Coppermine | 5 | 1,896 |
| 16 | Coral Harbour | 5 | 1,249 |
| 17 | Eskimo Point | 4 | 2,028 |
| 18 | Fort Franklin | 4 | 1,112 |
| 19 | Fort Good Hope | 3 | 97.5 |
| 20 | Fort Liard | 3 | 556 |
| 21 | Fort McPherson | 3 | 1,432 |

| Ref. No. | Plant Location | No. of Engines Per Plant | Total Capacity (kW) |
|---|---|---|---|
| 22 | Fort Norman | 3 | 1,098 |
| 23 | Fort Resolution | 3 | 964 |
| 24 | Fort Simpson | 4 | 5,565 |
| 25 | Fort Smith | 3 | 6,509 |
| 26 | Frobisher Bay | 4 | 9,810 |
| 27 | Gjoa Haven | 3 | 771 |
| 28 | Grise Fiord | 3 | 489 |
| 29 | Hall Beach | 3 | 820 |
| 30 | Holman | 3 | 545 |
| 31 | Igloolik | 3 | 1,245 |
| 32 | Inuvik | 4 | 11,704 |
| 33 | Jean Marie River | 2 | 70 |
| 34 | Lac la Marte | 3 | 462 |
| 35 | Lake Harbour | 3 | 805 |
| 36 | Nahannie Butte | 3 | 240 |
| 37 | Norman Wells | 4 | 2,514 |
| 38 | Pangnirtung | 4 | 2,084 |
| 39 | Paulatuk | 3 | 361 |
| 40 | Pelly Bay | 5 | 1,346 |
| 41 | Pine Point | 4 | 12,853 |
| 42 | Pond Inlet | 3 | 1,618 |
| 43 | Rae Lakes | 3 | 162 |
| 44 | Rankin Inlet | 4 | 3,602 |
| 45 | Repulse Bay | 3 | 652 |
| 46 | Resolute Bay | 5 | 4,530 |

| Ref. No. | Plant Location | No. of Engines Per Plant | Total Capacity (kW) |
|---|---|---|---|
| 47 | Sachs Harbour | 3 | 808 |
| 48 | Snowdrift | 3 | 431 |
| 49 | Spence Bay | 4 | 1,058 |
| 50 | Tuktoyaktuk | 3 | 1,994 |
| 51 | Whale Cove | 3 | 660 |
| 52 | Wrigley | 3 | 459 |
| 53 | Yellowknife | 5 | 11,548 |
| 54 | Dory Point | 4 | 446 |
| 55 | Fort Providence | 3 | 1,609 |
| 56 | Hay River | 10 | 8,799 |
| TOTAL | | | 145,911 |

# 3.0 METHANOL PRODUCTION

## 3.1 Review of Methanol Process Technology

### 3.1.1 Introduction

Methanol is a bulk scale chemical with a world wide consumption of approx. 18 million TPY (12.3 million TPY in 1981). Canada already has a number of major methanol producers including Alberta Gas Chemical Ltd., Celanese Corp. and Ocelot Industries Ltd.

The major areas of methanol consumption include:

- Paint manufacture
- Antifreeze Manufacture
- Formaldehyde based plastics
- Industrial Solvents

In the case of this study, it is planned to use the methanol as a fuel. This is in some ways similar to its use as a gasoline additive. For chemical uses, methanol with a purity of 99.8 per cent is required. For use as a fuel, a methanol purity of 98 per cent is adequate. The major difference between the two grades is in water content. The difference in economic terms is a lower investment cost and a lower steam consumption of 0.4 T steam/-tonne methanol for the fuel grade methanol. The product for this study is fuel grade methanol.

The conventional feedstocks for methanol are:

i) Natural Gas
ii) Fuel or Residual Oil
iii) Coal

The partial oxidation of residual oils and the gasification of coal using steam and oxygen have been used for methanol production in cases where these feedstocks have a large price advantage (between 30 per cent and 60 per cent) over natural gas. Since this is inapplicable in NWT, these will not be considered further. The majority of the existing methanol capacity is based on the use of natural gas as the feedstock. Plants based on this feedstock have been in existence for several decades, and this is a well developed process. The main changes which have occurred are:

i) World scale plant size has increased to the 1000 TPD to 2500 TPD range. The smaller plants are in the 200 TPD to 600 TPD range. Below 500 TPD centrifugal compressors give way to reciprocating compressors. In conjunction with larger synthesis gas plants to produce ammonia or hydrogen,

methanol synthesis loops of 30 to 60 TPD capacity have been installed, particularly for crude methanol make-up for rectisol gas wash streams. However, grass roots plants below 200 TPD are not economically viable.

ii) The low pressure methanol synthesis loop which operates in the 50 to 100 BAR range has displaced the older high pressure loops, i.e., 200 to 300 BAR range. There are two low pressure methanol synthesis loops:

1) Lurgi Low Pressure Methanol Synthesis
2) ICI Low Pressure Methanol Synthesis

In addition to the above, there is the medium pressure Haldor Topsoe synthesis loop. This is similar to the ICI process except that the operating pressure is 100 to 120 BAR. The waste heat is used for boiler feed water preheating, rather than steam generation.

### 3.1.2 Synthesis Gas Production

The above processes all require the production of a synthesis gas consisting of CO, H2 and $CO_2$. This gas typically also contains nitrogen and $CH_4$ which act as inerts and are to be minimized. The optimum stoichiometric ratio is:

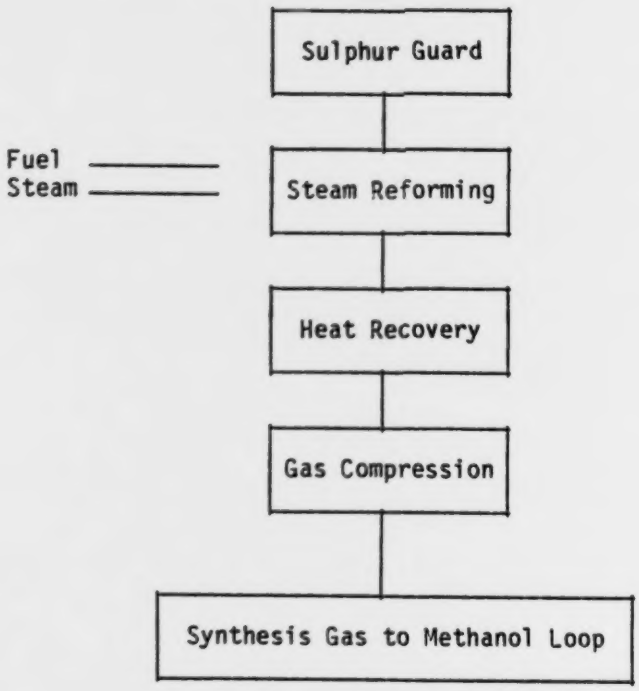
$$\frac{H_2 - CO_2}{CO + CO_2} = \text{approx. } 2.05$$

The approx. $H_2/CO$ ratio for the natural gas available is 3, whereas the optimum is nearer 2. Natural gas is partially deficient in carbon for optimum methanol production, and this increases the purge gas stream to be used for reformer fuel. This could be made up using an external source of $CO_2$. For purposes of this study this is not economically feasible, and no external $CO_2$ import or recovery from flue gas will be considered.

The natural gas should have a nitrogen content below 2 per cent, as nitrogen along with the residual methane acts as an inert in the methanol synthesis loop, increasing the circulating gas volume and purge gas requirements. The natural gas is available at a supply pressure of 120 to 300 BAR. For feed to existing steam reforming units it is required at 30 to 35 BAR. Hence, it can be let down through a turbine to generate electricity, at the same time eliminating the need for a natural gas compressor. The natural gas must be sulphur free. The copper based catalyst used for methanol synthesis is very sensitive to sulphur poisoning if the sulphur content exceeds 0.1 ppm. Hence, a zinc oxide bed is included as a guard against sulphur breakthrough.

If the hydrogen sulphide content is in excess of 20 ppm, the use of an activated carbon bed becomes necessary. For sulphur contents exceeding 200 ppm the use of a caustic wash or a physical absorption system such as selexol would be necessary. For this study, a zinc oxide guard is adequate.

The process sequence is as follows:




The steam reforming in typical commercial installations takes place with a natural gas feed at a pressure of 20 to 35 BAR. The natural gas is mixed with steam (produced by the waste heat recovery in steam reforming and methanol synthesis), and the mixture is heated at the inlet to the reformer furnace convection section, using the hot flue gases.

The ratio of steam/carbon is kept between 5 to 6 for this operation. The high steam/carbon ratio eliminates the need for a downstream CO shift conversion, and minimizes the unreacted methane. This is now fed into the high alloy tubes which are packed with a nickel based catalyst.

The reaction takes place at a bed temperature of 780 to 880°C and is endothermic. The sensible heat and heat of reaction is provided by burning the purge gas/natural gas in the reformer. The flue gas is available at 850 to 920°C and is cooled down with heat recovery.

The methane reacts with steam to produce CO, $CO_2$ and $H_2$. Typical reactions can be described.

$$CH_4 + H_2O = CO + 3H_2$$

$$CO + H_2O = CO_2 + H_2$$

The gas leaves the steam reformer at 770 to 870°C, and is cooled down to 35°C for feed to the make-up gas compressor. Since the gas is available at 60 BAR, there is the possibility of eliminating the make-up gas compressor, and cooling the hot synthesis gas down to 240°C for feed to the methanol synthesis.

Due to the non-availability of commercially proven steam reformers operating at 55 BAR pressure, this option has been excluded. This could be considered in any subsequent feasibility study as a cost reduction scheme.

### 3.1.3 Lurgi Low Pressure Methanol Synthesis

The Lurgi low pressure process has been extensively used in recent years for methanol production from natural gas.

The reformed gas containing less than 1.5 per cent inerts is compressed to 50 BAR at 120°C, and fed to the methanol synthesis loop.

In the shell and tube reactor, the tubes are filled with catalyst and the shell side is filled with boiling water. Reaction temperature (between 250-260°C) is controlled by the boiling water steam pressure.

Good reaction heat transfer to the boiling water gives 1-1.4 kg of steam per kg of methanol and protects the catalyst even at abnormal operating conditions. The reactor gases after the reactor feed/effluent exchanger are cooled and methanol is condensed and removed in a separator while the gas is recycled by the recycle compressor. A small portion of gas is purged and used as hydrogenation gas for desulphurization of the feedstock or as fuel.

The crude methanol is refined to a purity of 98%.

Economics: Typical requirements per metric ton of methanol are:

| | |
|---|---|
| Feed, GJ | 29.3 |
| Fuel, GJ | ---- |
| Electricity, kWh | 50 |
| Feedwater, tons | 0.75 |
| Chemical and catalysts, $U.S. | 1.02 |

3.1.4 ICI Low Pressure Methanol Synthesis

The ICI low pressure methanol synthesis process is another well established process for methanol manufacture.

The synthesis gas is compressed to 50 BAR, and fed to the synthesis reactor at a temperature of 120°C.

The synthesis gas is added to the synthesis loop which comprises the following items: circulator, converter, heat exchanger, cooler and separator. The crude product is distilled in two or three columns.

Main features of the process are: a highly stable copper based methanol synthesis catalyst, simple converter design and heat recovery and an optimized distillation system. The synthesis catalyst operates in the pressure range 50 to 100 BAR at 200 to 300°C and has a life of up to four years. The converter is a pressure vessel containing a single bed of catalyst. Catalyst can be loaded through the top of the converter and discharged at the base in a matter of hours. The reaction is quenched at several levels by cool gas injected through specially designed spargers. The last quench may be replaced by an interchanger which heats the feed to the first bed. This design allows heat to be removed at a higher temperature from the loop in boiler feed water and water for feedstock saturation. The overall heat recovery system involving the reformer and synthesis loop, together with the energy system is optimized to obtain maximum use of heat at all levels of temperature, thereby obtaining maximum economy in the consumption of feedstocks. The distillation section is optimized for capital cost and energy consumption.

Economics: Typical requirements per metric ton of methanol are:

| | |
|---|---|
| Feed and Fuel K cals x $10^6$ | 7.3 |
| Electric power kWh | 35 |
| Feed water $m^3$ | 1.15 |
| Catalysts U.S.$ | 1.5 |

### 3.1.5 Haldor Topsoe Medium Pressure Methanol Synthesis

The Haldor-Topsoe process is a low-energy, medium pressure process to produce fuel grade or chemical grade methanol from natural gas. However, unlike the Lurgi and ICI processes, Haldor-Topsoe has not been extensively used in commercial plants.

The synthesis gas produced in the reformer is a mixture of mainly $H_2$, CO and $CO_2$ with a considerable surplus of $H_2$.

Synthesis of methanol takes place at 65 - 85 BAR in three radial flow converters with indirect heat exchange between the converters.

The heat gained is used for boiler feed water preheating . Only part of the gas passing the converter system is converted into methanol, the remainder is mixed with fresh synthesis gas and recirculated. The surplus of hydrogen is removed in a purge stream, which also prevents inerts such as nitrogen and methane from building up in the synthesis loop. The purge gas is depressurized in an expander, supplying part of the moving power for compression of the synthesis gas. After expansion the purge gas is burnt as fuel in the reformer.

Ecomonics: Typical for operation with natural gas as feedstock. Figures are per metric ton of product:

| Product Methanol | Fuel Grade | Chemical Grade |
|---|---|---|
| Feed and fuel, kcal x $10^4$ | 7.3 | 7.3 |
| Steam, kg | -400 | 0 |
| Demineralized water, kg | 790 | 790 |
| Electric power, kWh | 15 | 15 |

### 3.1.6 Other Processes

Stone & Webster has developed a conceptual design for building a methanol plant using a new concept called power reforming, which replaces the conventional reforming used in other processes.

The power reformer incorporates a special catalyst packed heat exchanger (convective reformer) and a gas turbine. The tubes are filled with conventional reforming catalyst and the shell side fluid is pressurized flue gas. The flue gas from the reformer is expanded through a gas turbine which drives the combustion air compressor and generates additional power. A portion of the flue gas is recycled in order to control mass flow through the shell side of the reformer.

The use of power reforming allows a reduction of about 30 per cent in plant area when compared to conventional reforming. For example, a 1,000 TPD methanol plant using conventional reforming would occupy a plot of about 65m by 100m (6500$m^2$) whereas a power reforming plant would occupy a plot of about 60m by 75m (4500$m^2$). This reduction in plot area results in significant savings in offshore platform or barge construction. Power reforming results in smaller size equipment and less weight, which is more advantageous for platform design.

### 3.1.7 Mini-Scale Methanol Production

During the last two years the introduction of mini-scale plants sized to produce 30-40 tonnes per day methanol from natural gas productions of approximately 1 million SCFD (methane equivalent) have been proposed. It has been suggested that such plants, built as modularized, portable units can be moved quickly in and out of smaller, remote gasfields and produce useful fuels from gas reserves that would not otherwise be exploited. An announcement by Xytel Corporation which appeared in "Alcohol Week", December 26, 1983 is shown in Appendix 1. Similar announcements were released by Xytel Energy Limited, Burlington, Ontario in April 1984. Plants so described are of much interest for exploitation of large and small gas reserves in frontier areas and enquiries were made with both companies, resulting in the following observations:

1. There are no new methanol synthesis processes involved. The mini-plants are based on conventional steam reforming and medium pressure methanol synthesis (Haldor Topsoe) steps based on a gas feedrate of 1 million SCFD.

2. As of March 1985, no plants have been built and no detailed design engineering has yet been completed.

3. The cost estimates published are based on preliminary engineering concepts based on an assumption that the mini-plants can be modularized and pre-fabricated as units transportable by trucks and low-loaders.

4. The cost estimates published also do not include costs of storage or provision of utilities and offsites. These could include the installation of water treatment, boiler feedwater preparation, wastewater treatment and electic power generation and hence adds substantially to the indicated cost. In remote areas additional costs will also be incurred for provision of access roads and loadout facilities, communications and accommodation facilities.

The possibility of designing methanol plants of more conventional sizes, 300-2,000 tonnes per day, in modularized form suitable for

mounting on barges, tankers and offshore platforms has also been intensively investigated, including the effects of sea motion on the operation and performance of the catalytic and distillation units. Design studies and cost estimates for these plants indicated that, in general, capital cost requirements would be similar to those for land based plants, the cost of the barge, tanker, etc. being excluded. Typical ranges of costs are shown in Fig. 3.1.

At the present time, and in the absence of detailed engineering design and costing, it is assumed that it is technically feasible to construct transportable mini-methanol plants in range 20-50 tonnes per day, the total capital requirements for such installation being less, on an annual tonne of product basis, than conventional plants of sizes 300 TPD and larger. Resolution of the question will require consideration of a specific site location in NWT; fabrication facilities; transport facilities; and a design providing integration of the basic synthesis plant with the necessary offsites and storage.

## 3.2 Description of a Standard Methanol Plant Suitable for NWT

A plant of capacity 300 TPD is proposed based on the market data, as discussed in Section 2.

Natural gas is available, and the gas analysis based on data from the Parsons Field is used for the design basis, as specified in Table 3.1.

The plant site is adjacent to the town of Inuvik. This can be described as an inaccessible site in the permafrost, far away from the large industrial centres having difficult site conditions, limited local resources and severe access problems. The availability of local power is assumed to be less than 500 kW and cooling water is limited due to freezing of water sources, and hence air cooling is foreseen for all major duties. Make-up water should be held to a minimum except for process needs. The plant will be designed to incorporate a turbo alternator to cover all process plant needs plus 2 MW for administrative buildings etc.

Since operating and skilled construction labour has a large expatriate component and high cost, it is intended to use modular construction techniques and micro processor based control systems for process control operations.

The economic plant construction mode will be to assemble the modules in Edmonton, and then using a combination of land transports and barges, float the modules down the Mackenzie River to the site.

The actual land based site will have severe foundation and piling problems, due to the severe permafrost conditions. The alternative for a barge mounted plant was reviewed and considered to be uneconomic, but will require further investigation.

For the extremely low temperatures, the plant will be designed with special winterizing protection to permit operations at -65°C. This could result in the use of 3-1/2 per cent or 5 per cent Ni steel for many applications, or extra heated enclosures.

For the proposed plant, the feasible alternatives are the Lurgi and ICI processes. Lurgi has had more experience in the design of small-scale plants, and therefore is the proposed process for NWT.

The flow diagram for the process is shown in Fig. 3-2.

Natural gas at 35 BAR and 40°C is supplied to the plant where the gas passes through a bed of zinc oxide which acts as a sulphur guard. The gas then mixes with steam and the mixture is heated at the inlet to the reformer furnace convection zone by hot flue gases. The hot mixed gas feed stream then enters the catalyst packed tubes of the reformer. The tubes pass through the radiant zone of the reformer. The feed is converted to a gas mixture of hydrogen and carbon oxides by catalytic reaction and shift in the reformer tubes. A portion of the natural gas and purge gas is used as fuel to provide heat for reforming. Sensible heat in the combustion gas is recovered by feed preheat and by generating superheated and saturated steam at various levels and by preheating combustion air to the reformer. Flue gas at approximately 175°C is discharged to the atmosphere. Reformed gas leaving the reformer at approximately 865°C supplies additional heat for steam generation and boiler feedwater preheat. The reformed gas is finally cooled to 45°C, condensed water is separated, and the reformed synthesis gas is fed to the synthesis gas compressor.

The synthesis gas compressor is a two stage machine which compresses the synthesis gas from 28 BAR to 52 BAR. Recycle synthesis gas mixes with the feed in the second stage and is compressed to the methanol synthesis reactor inlet pressure. The total synthesis reactor feed is heated to the reactor inlet temperature by the hot reactor effluent gases at 255°C. The methanol synthesis reactor feed gas flows to the methanol synthesis reactor. The Lurgi low pressure process for methanol synthesis utilizes a shell and tube reactor. The reactor tubes are packed with a copper based catalyst. The methanol synthesis reaction is highly exothemic. The heat of reaction is utilized to generate steam on the shell side of the reactor.

Reactor effluent gas containing the raw methanol, after being partially cooled in the feed/effluent exchanger, is further

indirectly cooled and condensed by cooling water. Uncondensed gases are separated from the mixture and are recycled to the synthesis gas compressor. The methanol-water condensate is sent to the two tower purification section.

The first tower in the purification section is a distillation column which separates light ends overhead. This distillation off-gas stream is utilized as auxiliary reformer fuel. The bottoms product from this column flows to the second tower, another distillation column wherein the methanol in the feed is distilled overhead as 98 per cent pure methanol.

NATURAL GAS REQUIREMENTS AND SPECIFICATIONS

A 300 MTPD Lurgi low pressure process methanol plant utilizing natural gas requires a total volumetric flow of 10,325 normal cubic metres per hour gas as feedstock and fuel. This does not include the natural gas requirements for power generation.

The energy equivalent of the total natural gas required, based on a natural gas Lower Heating Value (LHV) of 9089.1 kg.cal/ncm, is 93.8 million (MM) kg.cal/hr. The equivalent energy consumption per unit of product is 7.5 MM kg.cal/MT methanol.

CHEMICALS AND CATALYSTS REQUIREMENTS

Additional raw materials requirements, as chemicals and catalysts, needed to operate a 300 MTPD Lurgi low pressure process methanol plant are summarized in the following tables:

CHEMICALS

| | | |
|---|---|---|
| $H_2SO_4$, 90% | - | 6,300 kg/yr |
| NaOH, 20% | | 33,000 kg/yr |

Commercial low pressure process methanol synthesis catalysts are composed of Cu/ZnO, Cu/ZnO/$Al_2O_3$, and Cu/ZnO/$Cr_2O_3$. These catalysts are all sensitive to poisoning by chlorine and sulphur and may not be used at temperatures above 300°C. Copper, dissolved in ZnO, is the active species.

UTILITIES REQUIREMENTS

Utilities consumption for a 300 MTPD Lurgi low pressure process methanol plant, utilizing a natural gas feedstock, are summarized in the following table:

| | |
|---|---|
| Electricity Generation | 12 MW capacity for plant, offsites and community needs |
| Make-up Water, $m^3/hr$ | 14 |
| Instrument Air, ncmh | 72 |

ENVIRONMENTAL CONSIDERATIONS

The production of methanol from desulphurized natural gas does not present any serious pollution problems. The major waste streams produced are the flue gas from the tubular reformer and the waste water bottoms from distillation.

PLANT AREA REQUIREMENTS

A 300 MTPD methanol plant utilizing the Lurgi low pressure process, and including product storage facilities can be situated on a parcel of land approximately 10,000 $m^2$ in area.

TABLE 3.1

NATURAL GAS ANALYSIS: PARSONS LAKE

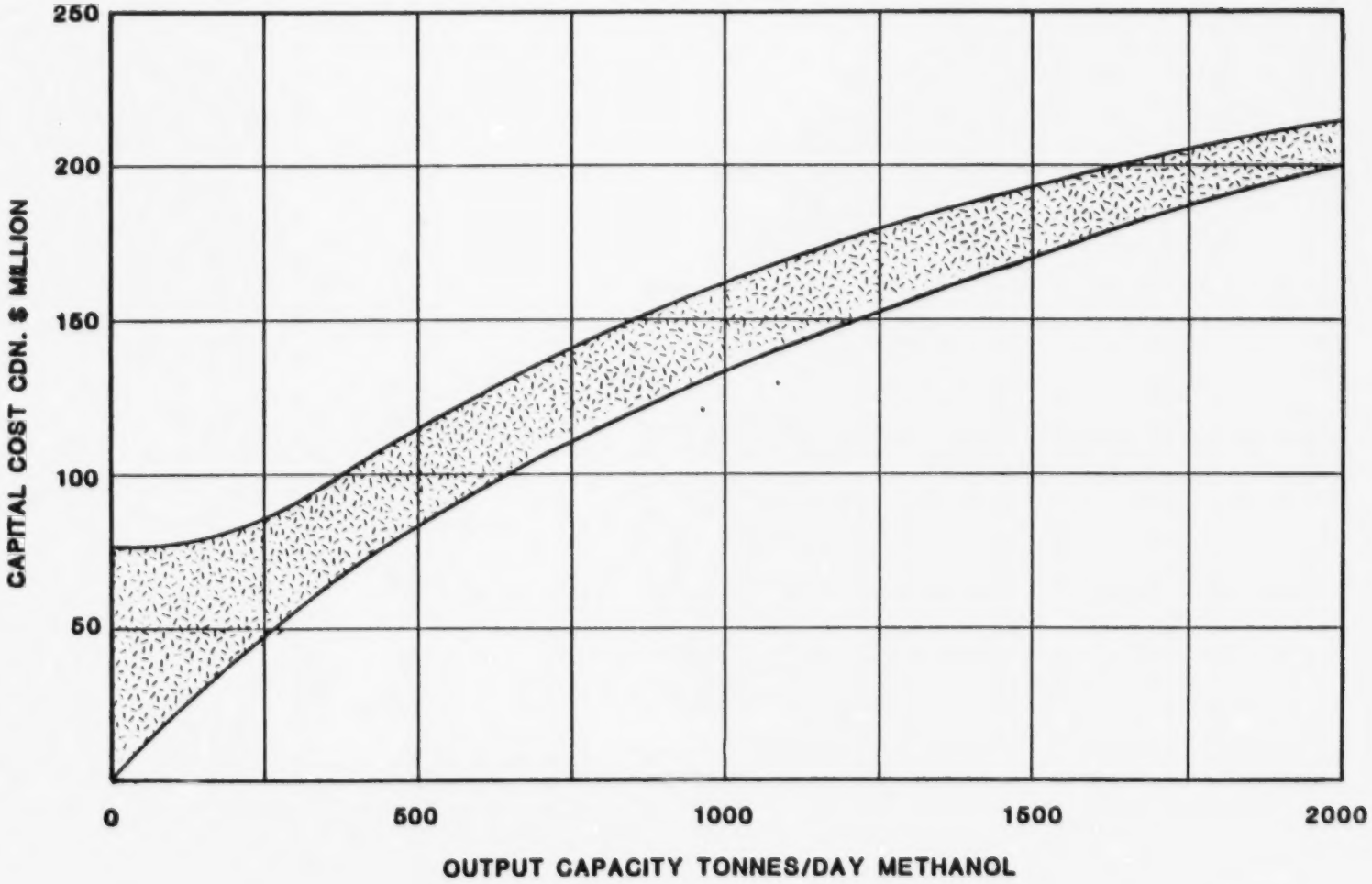
| Component | Mole % |
|---|---|
| $N_2$ | 1.49 |
| $CO_2$ | 2.72 |
| $C_1$ | 88.82 |
| $C_2$ | 3.80 |
| $C_3$ | 1.57 |
| $iC_4$ | 0.27 |
| $nC_4$ | 0.46 |
| $iC_5$ | 0.16 |
| $nC_5$ | 0.15 |
| $C_6^+$ | 0.56 |
| | 100.00 |

Pressure = 287.6 BAR

Temperature = 80°C

S.G. = 0.652

## FIG. 3.1 CAPACITY/COST RELATIONSHIPS FOR STANDARD METHANOL PLANTS



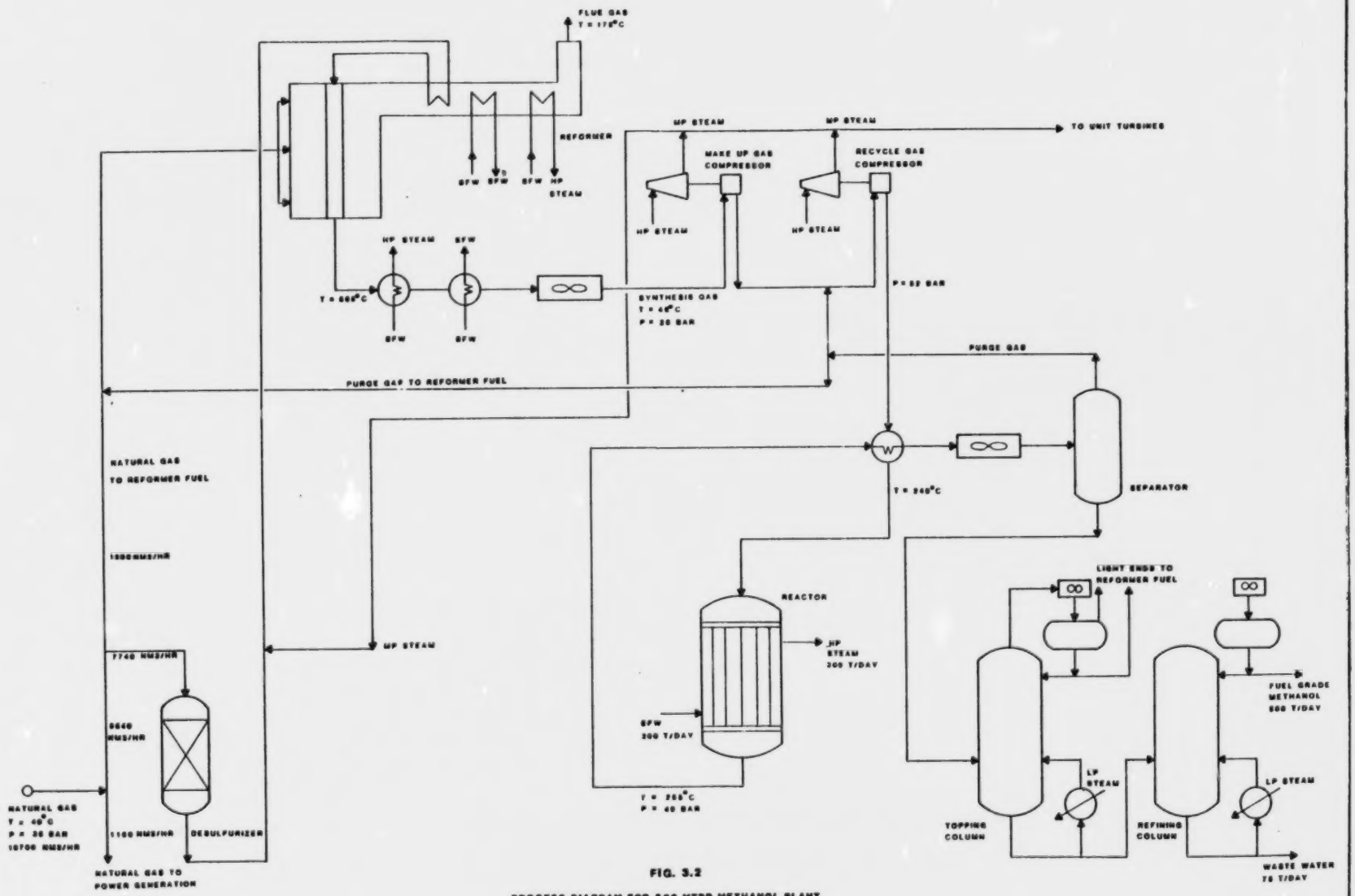



FIG. 3.2

PROCESS DIAGRAM FOR 300 MTPD METHANOL PLANT

USING LURGI LOW PRESSURE PROCESS

## 3.3 Capital and Operating & Maintenance Costs

### 3.3.1 Capital Costs

Total installed capital investment (TIC) for a 300 TPD methanol plant described in outline in Section 3.2 is estimated at $85 million Canadian, as of January 1985.

An approximate apportionment of this order of magnitude TIC is as follows:

| | $ (million) |
|---|---|
| Inside Battery Limits (ISBL) | |
| Desulphurization and Steam Reforming | 27.6 |
| Methanol Synthesis | 39.7 |
| Methanol Distillation | 5.5 |
| Total ISBL | 72.8 |
| Outside Battery Limits | |
| Storage tanks, product loading and transfer, power generation, water treatment, flare system | 12.2 |
| Total installed cost | 85.0 |

### 3.3.2 Operating & Maintenance Costs (O&M)

The O&M costs shown in Section 6 are based on the following:

| | |
|---|---|
| Plant Manpower (including Management and Supervision) | 35 |
| Maintenance | 3% of TIC |
| Productive Supplies (Chemicals - catalysts) | $0.6 MM/year |

Feedstock costs (natural gas) are generated in the analysis against attributed fuel oil costs.

## 4.0 SUITABILITY OF METHANOL AS A SUBSTITUTE FUEL

4.1 The characteristics of methanol which have most effect on its suitability as a substitute fuel are discussed below.

4.1.1 Higher heating value

| | |
|---|---|
| Methanol | 18,093 kJ/l |
| Gasoline (Typical) | |
| No. 2 Oil | 41,757 kJ/l |
| No. 6 Oil | 38,251 kJ/l |
| Diesel | 38,001 kJ/l |

The relatively low heating value implies that where methanol is a substitute, fuel handling and storage systems have to be doubled in capacity. It also implies that the volume of fuel delivered to a particular location has to be doubled as well.

4.1.2 Volatility

Methanol has a low vapour pressure relative to gasoline. This feature makes cold starts on pure methanol impractical below about 9°C.

4.1.3 Solubility and Water Sensitivity

Methanol is infinitely soluble in water and completely soluble in dry gasoline.

Water (about 0.1 per cent) when combined with low temperatures will cause phase separation of methanol-gasoline blends.

Small quantities of water in straight methanol are tolerable in internal combustion engines, boilers and gas turbines, and are beneficial in reducing $NO_x$ emissions.

4.1.4 Corrosion, Swelling and Engine Maintenance

Severe corrosion of zinc, lead and magnesium occurs with methanol. Aluminum and copper are also more severely affected by methanol than by hydrocarbons. Such materials need to be coated or lined with inert or methanol resistant coatings. Other parts and materials used in engine and fuel systems would require review for methanol compatibility.

Methanol is a strong solvent and noticeably swells or softens many of the plastics or rubbers commonly used as gaskets or floats in conventional hydrocarbon fuel systems. Water contained in methanol can corrode unprotected steel.

The low lubricity of methanol may also cause increased wear in some engines and pumps.

Methanol is a clean burning fuel which should prevent the build-up of undesirable deposits in combustion chambers and furnaces.

4.1.5 Knock Resistance and Octane Rating

Methanol has high knock resistance and octane rating. This high rating permits considerably higher compression ratios for methanol relative to gasoline, permitting greater efficiency and power. Blending of methanol in small quantities with gasoline increases octane rating considerably more than the alcohol proportion added. This effect is more noticeable with low base gasoline octane numbers.

4.1.6 Ignitability

Cetane number, a measure of the ability of a fuel to self-ignite under compression-ignition conditions is extremely low for methanol, less than 10, compared with 40-60 for North American diesel fuel. To make methanol suitable as a fuel in diesel engines an ignition enhancer is necessary.

4.1.7 Luminosity and Particulate Formation

In a pure state methanol burns with a clean bluish flame with low luminosity. Radiation transfer is consequently lower with a methanol flame than with petroleum based flames and can be a disadvantage if high amounts of radiant heat are required.

In boiler applications, methanol flames will remove soot deposits left by previous fossil fuels, and retain good conductive heat transfer throughout the boiler heating surfaces.

4.1.8 Viscosity

Methanol has much less lubricity than petroleum products. This factor can require fuel pump modifications in engine use.

4.1.9 Emissions

The lower flame temperature of methanol results in substantially lower $NO_x$ emissions. Tests recently carried out on a gas turbine in California show $NO_x$ emmission levels of approximately 45 ppm for methanol versus 144 ppm for natural gas and 207 ppm for light oil. California's South Coast Air Quality Management District passed legislation in 1984 restricting all new cogeneration facilities to either using selective catalytic reduction devices or burning methanol to limit $NO_x$ emissions.

Particulates, sulphur compounds, lead and polynuclear aromatic hydrocarbons (PNA) are absent from alcohol fuel emissions.

4.1.10 Safety, Toxicity, and Environmental Hazards

Methanol is toxic and is labelled a "poison". Ingestion can cause blindness and death, and it is clearly more hazardous in this regard than gasoline. Special procedures, similar to those used for other widely utilized toxic substances, are therefore required in handling this chemical.

In terms of flash point and autoignition temperature, methanol appears somewhat less hazardous than gasoline.

Flammability limits and lower vapour pressures suggest that methanol presents explosion hazards that may be more serious than those of gasoline; however, the lower vapour pressure of methanol reduces the chances of fire if spilled. A small quantity of butane mixed with methanol might remove any special hazard relative to gasoline; in lieu of some such corrective measure, vapour spaces should be protected from flashback by a flame arrester.

Methanol fires are considered easier to control than hydrocarbon fires; some authorities state that water can be used successfully on alcohol fires; once the methanol is diluted below fifty per cent concentration, the mixture will no longer burn. Other authorities state that carbon dioxide or dry chemicals, the same extinguishing agents as for gasoline, should be used to extinguish methanol fires.

Environmental hazards to land and water are generally far lower with methanol than with petroleum liquid fuels:

a) Methanol burns at a lower temperature; reduced $NO_x$, CO, and hydrocarbon emissions occur while aldehyde emissions increase somewhat; no lead, sulphur, soot or other particulates occur.

b) Accidental spills of methanol in harbours, streams, lakes or offshore would have minimal consequences; no fire or environmental hazard would normally occur due to the rapid diffusion and complete miscibility of alcohol with water; methanol is rapidly biodegradable to $CO_2$ and water.

c) Methanol would be toxic to most plants, animals and aquatic organisms if it is not diluted and is heavily concentrated; some bacteria thrive on methanol, which is being actively considered as a feedstock in growing single cell proteins.

Research at the University of Santa Clara examined biological hazards of methanol spills. The effects of immediate spills or leaks were concluded probably to be minimal except in a very proximate area where concentrations reach one per cent. Since methanol is quite miscible, volatile and degradable, gross environmental impact from moderate spills is unlikely.

Research by the Union Oil Company noted that there is little toxic hazard with methanol-gasoline blends (relative to gasoline); with neat methanol, toxic hazards would be greatly reduced simply by adding five per cent or more gasoline (or lower concentrations of a warning odorant such as mercaptans) which would ensure appropriate warning odors.

Previous research by the Energy Research & Development Agency in the U.S. and work at Biomedical Resources International (Toronto) highlight the following for alcohols relative to petroleum fuels:

(a) Reduced emissions occur from alcohol fuels used in vehicles (emphasis on photochemical oxidant formation, lead and sulphur emissions, and carcinogenic hydrocarbons that are reduced or eliminated).

(b) Reduced gross environmental impacts are likely from major spills.

(c) Comparative toxicity ratings indicate that methanol is generally equally or less hazardous than gasoline; ethanol is somewhat less hazardous than methanol. Gasoline is much more toxic on inhalation than methanol and gasoline vapours are more carcinogenic. Methanol is generally more toxic through ingestion than gasoline unless the benzene content in gasoline is high.

(d) Similarly, gasoline and alcohols are rated as having similar fire hazards.

(e) A need exists, however, to define proper procedures for low-level methanol leakage risks, methanol spill clean-up procedures, specific alcohol safety and health procedures.

## 4.2 Power Generation

### 4.2.1 Gas Turbine

4.2.1.1 Gas turbines appear to be the most likely candidate for early conversion to methanol fuels. Various tests on methanol have been carried out, primarily in California, with one test on a 3200 kW Allison gas turbine being due for completion in March 1985.

4.2.1.2 The efficiency and specific output of gas turbines burning methanol fuel significantly different from those of gas turbines burning conventional fuels. Tests carried out on gas turbine units buring 100 per cent methanol have shown an increase in unit efficiency and power output. Typical efficiency rises have been 1-2 per cent and power outputs rose by 6 per cent.

Reliability of gas turbines using methanol has still to be completely proven. Most study papers that have addressed maintenance requirements and down time state that they should be lower when using methanol fuel. The most definite statement would seem to be that performance would be similar to those of natural gas fired units.

Flexibility of operation is not expected to be a factor in comparing methanol and distillate fuels. Both are liquid fuels and present no significant time delay or stability problems. Methanol, in tests conducted by General Electric, was shown to have the following operating characteristics:

a) Methanol ignition characteristic is within the manufacturer's standard operating limits.

b) The combustion of methanol provides sufficient temperature rise to allow the turbine to accelerate to full speed - no load condition.

c) The flame produced by the combustion of methanol is stable over the wide range of fuel/air ratios. No problems were experienced when the unit was at full speed and had to operate at various loads while the air flow remained constant.

d) The flame produced by the combustion of methanol does not blow out in the event of a sudden load drop to no load.

e) The combustion of methanol produces a good temperature distribution at the inlet to the first turbine stage.

4.2.2 Steam Generators

4.2.2.1 A study carried out by the U.S. Electric Power Research Institute in 1981 concluded that "With an ample availability and competitive price, methanol would be an excellent, low $NO_x$ producing fuel for use in utility boilers." However, it added that the use of methanol in the electric utility "is not practical today because of the current high cost of methanol and its limited availability." 406,000 gallons of methanol were burned in 73-1/2 hours in a 44.5 MWe balanced draft boiler.

Some derating in capacity and decrease in efficiency was experienced. The decrease in efficiency is due to increased water vapour loss in the flue gas and was approximately 7 per cent.

From the point of view of reliability, a methanol-fired unit should be similar to an oil fired unit, without the need for sootblowing. Low flame luminosity of methanol would only be a problem in units with high degrees of steam superheat section. Saturated steam production or hot water generation would not be seriously effected.

4.2.3 Diesel Generators

4.2.3.1 The use of methanol in diesel engines is well documented. The vast amount of research and trial demonstrations has been aimed at the use of methanol or methanol-diesel blends in automobile, truck and bus diesel engines with no apparent test program related directly to power generation.

4.2.3.2 A summary of the potential problems associated with the use of methanol in diesels is as follows:

a) Low cetane number limits capability to auto-ignite.

b) High heat of vapourization limits cold start capability and increases wear.

c) Low lubricity of methanol increases wear.

d) Low temperature corrosion caused by nitric acid formation at start up and cool down.

4.2.3.3 Techniques investigated and developed to date for improvement of combustion include the following:

a) Dual fuelling, such as fumigation and dual high-pressure injection.

b) Blending of the methanol into diesel fuel by means of stabilizing agents or high turbulence mixing devices.

c) Modifications converting the engine to a spark-assisted engine (stratified charge).

d) Improving the auto-ignition properties by fuel additives.

4.2.3.4 Spark assisting and auto-ignition improvement allow the use of neat methanol as the fuel. Dual fuelling and blending need some diesel fuel to start ignition and/or to control combustion.

4.2.3.5 Spark or glow plug assistance involves actual modifications to the engine itself to locate the necessary spark or glow plugs.

4.2.3.6 The dual fuelling fumigation method involves the introduction of methanol into the incoming combustion air. The dual high-pressure injection method employs two separate injection systems, one for methanol and the other for diesel fuel.

4.2.3.7 With blending, methanol and diesel fuel are injected into the combustion chamber as a prepared emulsion.

4.2.3.8 The two solutions which, at this stage, appear most viable for use in the Northwest Territories are auto-ignition improvement and dual injection. Normal commercially available diesel ignition improvers can be used to increase cetane numbers but high additive concentrations are required (15 per cent by volume). Recent developments using certain nitrate esters and other organic compounds show potential for only a 5 per cent volumetric requirement. These compounds include:

Tetrahydrofurfuryl nitrate
Triethylene Glycol dinitrate
Tetraethylene Glycol dinitrate
Hexil nitrate
2 - ethylene nitrate

Advanced cetane improvers are very costly, approximately $4 per litre, and it is obviously desirable to minimize their use. As the current limited market increases, however, their price should decrease.

The use of cetane improvers involves minimal engine charge, hence least capital cost, but it has a higher associated fuel cost.

4.2.3.9 Dual fuel injection, i.e. direct injection of methanol with a diesel ignition spray can substitute up to 95 per cent by volume of the diesel formerly consumed. Tests have been carried out on locomotive diesels (660 hp) in Brazil and on 188 kW truck diesels in Germany. The Brazilian conversion was based on the following highly relevant criteria:

a) The adaptation should be easily implemented on the existing engines, and the parts, if possible, should be available in Brazil.

b) It should be possible to run the engine on straight diesel in such a way as to ensure its continuous operation independently of methanol availability.

c) The operational controls of the locomotive should be kept the same, as well as its power and driveability. The load control and the variation of pilot amount should be carried out automatically.

The results of the above test were sufficiently encouraging so as to prompt a current similar program on a 2000 hp locomotive of a type that carries 70 per cent of the railway traffic load in Brazil.

4.2.3.10 Further development work is necessary on the various alternative methods of using methanol as a fuel in diesel engines before any final decision can be made as to the best solution. Furthermore the wide variety of diesel manufacturers and range of installed capacities in NWT implies that one method may not be the best for all.

4.2.3.11 Cold start capability can be countered by either using an alternate fuel for start-up as in dual fuelling or by means of pre-heating (vapourizing) the methanol. These solutions also serve to counter excessive wear found in manifolds and cylinders attributed to the presence of liquid methanol. Wear rates are also minimized if lubricating oil is preheated before the unit is started.

4.2.3.12 Low lubricity in the fuel system is not critical if special delivery valves and pumps are used. Erosion resistant injectors are also necessary. Special oil additives which have been designed for methanol further reduce wear rates.

4.3 Domestic Heating

4.3.1 Nearly 60 percent of domestic heating in NWT uses hot air furnaces as the heating medium, with steam or hot water heating being the next most common method at 20 per cent. Stoves or space heaters are responsible for heating 15 per cent.

4.3.2 District heating by hot water is used in two locations, Inuvik and Frobisher Bay.

4.3.3 Research into the potential use of methanol as a domestic heating fuel is very limited. Some work has been done in EMR's Canadian Combustion Research Laboratory and in Japan. Both research programs produced results favourable to the use of methanol.

4.3.4 The Canadian program investigated the use of methanol as a fuel in a standard warm air furnace, typical of that used for firing natural gas or light oil. On completion of tests on a standard furnace, a retrofit condensing furnace, which captures the high amount of latent heat normally lost in the flue gas moisture content, was installed.

The tests concluded that methanol can be burned in conventional oil furnaces using a flame retention head burner, with steady state efficiencies of about 80 per cent with a retrofit condensing heat exchanger.

However, because of low methanol lubricity further development work on a methanol compatible pump is necessary.

4.3.5 The Japanese program investigated the use of methanol in kerosene type space heaters. A standard convective type space heater was used for the tests. The tests concluded that a kerosene burning heater was capable of burning methanol without any combustion chamber modifications. Thermal efficiencies are comparable and the emissions of potentially harmful, unburned combustibles are negligible.

4.3.6 From the above it is concluded that all domestic, commercial and institutional needs for space heating that currently use light oil or kerosene can be easily converted to methanol use.

4.3.7 As stated previously in section 4.2.2, district heating using methanol as a fuel is feasible as well.

4.4 Combined Heat/Power Systems (Cogeneration)

4.4.1 Cogeneration as such is not practised in NWT. Use of waste heat from diesel engines is carried out and the use of methanol as the fuel source should not affect this capability. In fact, zero sulphur content in methanol should make further waste heat capture possible in existing installations which have existing sulphur corrosion limitations.

4.5 Transportation Fuel

4.5.1 Spark-ignition Engines

4.5.1.1 Corporative gasoline and alcohol bench and road tests have been conducted on a variety of spark-ignition engines, using methanol in various ways as follows:

a) as a sole fuel component, with or without water
b) as a blending agent with gasoline
c) as a dual fuel with gasoline

4.5.1.2 The experimental results reported depend largely on test conditions, particularly on any increase of carburetor jet sizes, warming or weakening of the mixture, optimization of ignition timing, and raising of compression ratio. Nevertheless, in changing from gasoline to methanol fuel, the following broad conclusions can be drawn:

a) The higher stoichiometric fuel/air ratio of methanol causes mixture-weakening effects unless carburetor jets are modified.

b) Higher vapourization enthalpy of methanol lowers charge temperature by approximately 30°C unless compensated by manifold temperature control.

c) Improved Research Octane Numbers of methanol blends permits higher compression ratios.

d) Because of higher vapourization enthalpy cold starting of methanol blends is poorer and is generally impracticable below 7-9°C.

e) Methanol blends, being cleaner burning, produce less soot. Lower flame temperatures may require larger capacity car and truck heaters in NWT.

f) Equal quantities of co-solvents (ethanol and other higher alcohols) may be necessary as blend components to overcome the effect of small quantities of water in methanol on phase separation tendencies.

g) Care will be necessary in choosing engine lubricating oils because of viscosity, corrosivity and other changes that may result from methanol addition.

4.5.2 Compression-ignition Engines

4.5.2.1 When used in a C-I engine, methanol poses a major problem owing to its very low cetane number, making necessary the addition of an ignition enhancer to bring the cetane number up from less than 5 to over 30. However, ignition enhancers are costly, and still subject to further research. An alternative system is to operate on diesel fuel at low load, with methanol added at high load to the injection pumps, direct to the injectors, or by aspiration. In high-speed diesels, the concentration of methanol in diesel fuel is presently limited to about 50 per cent.

4.5.2.2 The dual-fuel approach appears more promising, with two separate fuel injection systems, the high ignition-quality fuel being injected first in order to promote ignition, followed by the methanol or methanol blend.

4.5.2.3 Spark-ignition has also been tried, with some success for truck engines, but much higher voltages are required at the high compression pressures. Glow plugs show promise for further development as well.

4.5.2.4 The complication of transient conditions and fast load changes experienced in road transport makes methanol usage more attractive in the larger single-speed industrial type of engine.

4.5.2.5 Further details on the above are given in section 4.2.3.

4.5.3 Automobile Engine Warranties

4.5.3.1 A summary of automobile manufacturers' positions on the use of methanol fuels in 1984 model year vehicles is shown below:

| Manufacturer | Comments |
|---|---|
| General Motors | Up to 5 per cent with co-solvent |
| Chrysler | Do not use, may void warranty |
| Ford | "May be injurious to fuel system" |
| AMC/Renault | Do not use over 3 per cent |
| International Harvester | Do not use, will void warranty |
| Honda | Not recommended |
| Toyota | Do not use over 5 per cent |
| Mazda | Not approved |
| Subaru | Do not use, may void warranty |
| Nissan | Not addressed |
| Fiat | Not addressed |
| Mercedes-Benz | Not addressed |
| Volvo | Not addressed |
| Saab | Do not use, may void warranty |
| BMW | Do not use over 3 per cent |
| Jaguar Rover Triumph | Do not use over 3 per cent |
| Volkswagon | Do not use |
| Peugot | Not recommended |
| Isuzu | Not addressed |
| Mitsubishi | Not addressed |

4.5.4 It is concluded that methanol does not currently represent a viable potential substitute for use in road transportation in NWT. Further development work is necessary and it is felt that methanol would have to be in more common use elsewhere in Canada, i.e., in areas where winter conditions are less severe, before it is even considered in NWT. The potential for fuel substitution in the road transportation sector appears to be low.

## 4.6 Methanol Transportation and Distribution

### 4.6.1 Introduction

4.6.1.1 Bulk methanol transportation is well established in other parts of Canada where it represents an important chemical feedstock.

Celanese Canada, as part of an organization that is the world's largest producer of chemical grade methanol, uses standard gasoline type rail tankers, truck tankers and even barge systems for the Gulf of Mexico area. Tanks used for methanol transportation are dedicated to this use only but this is for product quality protection purposes.

Vapour recovery, commonly used for gasoline also, is practised when loading or unloading methanol. This is necessary to meet environmental requirements.

4.6.1.2 When addressing methanol transportation from a fuel point of view, it should be remembered that chemical grade methanol is transported regularly in bulk shipments of up to 1,000,000 US gallons (30 train cars of 30,000 US gallons each) without problems.

The introduction of methanol as a fuel into NWT should not present any real problems from a transportation point of view. New technology is not involved; it is merely borrowed from the existing tried and proven chemical grade methanol technology.

### 4.6.2 General

4.6.2.1 Methanol fuels would require changes in existing fuel distribution and storage systems in order to resolve specific problems related to materials compatibility, hazards, storage and pumping capacity requirements for a separate fuel, greater fuel throughputs than would be required for petroleum products (due to the lower energy content of methanol), and (in the case of blends) prevention of water penetration.

4.6.2.2 Nevertheless, methanol (unlike hydrogen or LPG) does not require any unusual, unique, or highly specialized equipment for distribution or storage; existing pipeline, tanker, truck, barge and other systems used for petroleum products would be used for methanol (after modification where needed to meet any special problems), in the same manner as these facilities are presently used to handle a variety of petroleum products (including, for example, such totally incompatible products as leaded and unleaded gasoline).

4.6.2.3 In general, the introduction of distribution and storage systems for any pure methanol would therefore lead to problems directly analogous to the widespread introduction of any additional petroleum products, e.g., regular unleaded gasoline and diesel fuel and/or premium unleaded gasoline; oil industry officials note that introduction and use of pure methanol fuel would in one important aspect create less problem than the introduction and use of unleaded gasoline, (unleaded gasoline presents major initial costs as well as significant ongoing costs to prevent inter-product contamination, e.g., costs to clean out tanks, tankers, pipeline facilities, etc. which have been, and continue to be, used to handle leaded gasoline, plus ongoing quality control costs, etc.). In contrast, not incompatible with petroleum products, actual pipeline tests done moving methanol and gasoline in alternate batches indicate that any slight interaction between the two products would probably be mutually beneficial. It can also be noted that pure methanol will absorb, on an ongoing basis, any water seepage into the fuel distribution system, thereby tending to reduce problems in this area (except perhaps in cases where methanol is blended into a basically gasoline fuel).

4.6.3 Problems

4.6.3.1 Materials compatible with methanol would be needed in cases where pure methanol fuels or blends in excess of about 10 per cent methanol were distributed; bimetallic couples in existing tankage must be eliminated, and carbon steel tanks with fibreglass laminate linings would require treatment (probably a coating with a plastic) to prevent corrosion; aluminum fittings on tank trucks would probably have to be modified or coated. Costs for these changes would be small in relation to overall system costs for distribution, and provision of reasonable planning time would permit many adjustments to be integrated (at no significant added cost) into the normal equipment replacement process.

4.6.3.2 Special hazards would probably result in a new set of government fuel handling regulations (such regulations currently exist for gasoline); potential requirements would probably relate only to the handling of pure methanol and in this case would include the addition of a trap to prevent escape of alcohol vapours from existing tankage; vapour recovery systems for tank filling would be desirable to minimize exposure and possible toxic effects (similar future requirements, however, are anticipated in many areas for gasoline to meet safety and clean air criteria).

Explosion hazards for pure methanol tanks could be handled by addition of flash arrestors (to prevent flashback and possible ignition of flammable mixtures within a tank); alternatively, this problem (as well as problems relating to lack of flame visibility during fires and the risk of toxicity hazards due to intentional ingestion) could be removed by the addition of a small amount of hydrocarbons to the fuel (5 vol. per cent pentane or 10 vol. per cent gasoline would make the vapour too rich to ignite at temperatures down to 0°C or below; such mixtures would also ensure a more luminous flame, while dilution with water would produce an unattractive milky mixture with very strong gasoline odor). An alternative way to minimize pure methanol toxicity hazards is to use another warning odorant such as mercaptans. No special hazards are anticipated for methanol blends with significant amounts of gasoline.

Water penetration is viewed as a special problem only in cases where methanol blended as a portion of gasoline fuel (i.e. water penetration should not be a special problem if 5 to 20 per cent gasoline is blended with methanol.

4.6.2.4 Distribution and storage system cost impacts associated with methanol fuel use will vary with different segments of the system, the anticipated fuel volumes and end-uses, the anticipated overall trend for other fuel products, and the time period provided for methanol fuel introduction.

(a) Pipelines: methanol has lower viscosity than petroleum products, and thus would probably move through pipelines at a significantly lower cost (for pumping) per gallon than oil products; in addition, relative costs for moving methanol would be reduced due to the absence of any significant product contamination problems.

(b) Tankers, barges and other non-pipeline movements: ongoing cost differences per gallon between methanol and petroleum products would be minimal. Methanol weighs marginally more per gallon than gasoline; in addition, if methanol was destined for use in gas turbines it would be relevant to take special care to prevent contamination with brackish or sea water. In general, however, methanol would use the

same facilities as used for other petroleum products and would present far less problem than unleaded gasoline distribution with regard to inter-product contamination. Provided that methanol penetrated any significant share of the market, no special costs would occur due to small volume movements.

(c) Bulk Storage: costs of fuel storage in NWT must increase as the vast majority of fuel would be delivered in the short summer period, requiring a doubling of storage capacity at the point of delivery. As many residences in the remoter areas of NWT would appear to have fuel tanks sized for one year's consumption, it may be more cost effective to consider additional centralized storage distribution centres.

## 5.0 REGULATORY FACTORS

The principal areas covered by legislation and regulation are: taxation; safety and health; environmental protection. The first of these, taxation, is an element of governmental fiscal policies and is not part of this study . The other two areas, in relation to methanol, are subject to controls imposed by a large number of statutes and regulations. For example, it has been recently reported that a review of federal, provincial and municipal statues by the Ontario Ministry of Energy identified almost 30 of relevance to methanol fuels, none of which, however, appeared to raise significant legal barriers to their commercialisation.

### 5.1 Safety and Health

Regulations governing or relating to methanol (methyl alcohol, $CH_3OH$) are to a large extent dependent upon whether it is regarded as a chemical or as a bulk industrial fuel. A general discussion of the fuel characteristics of methanol has been provided in Section 4.1. To some extent these are determined by whether it is regarded as a blending supplement to bulk petroleum fuels, which has been the usual case until the present time, or whether it is regarded as a neat fuel carrying only small quantities of certain specialty chemicals necessary to improve its ignition or other fuel characteristics.

In its uses as a chemical, for example, as a solvent or chemical intermediate, some wide differences exist in governmental attitudes. Thus, in Canada and the USA, methanol is generally classified as a hazardous substance subject to control under the relevant Hazardous Substances Acts. In West Germany, however, methanol is a listed poison subject to the much stricter laws governing sale, storage, labelling etc. to the extent that, at the present time, the uses of methanol as a fuel component are not possible. In the European Economic Community the Directives on the handling of dangerous substances make no distinction between the handling of methanol and conventional fuels and it is recognized by West Germany that some changes in legislation to bring it in closer line with EEC Directives will be necessary before methanol can be introduced as a bulk fuel.

A general listing of the physical properties of methanol are given in Table 5.1. An account of the toxicity of methanol and relevant American regulations are provided in Appendix 2.

In the United States, the ready availability of bulk qualities of methanol surplus to the needs of the chemical industry has already resulted in the production and sale of blended methanol gasolines, permitted under temporary variation orders on the existing state and federal laws.

[1. Petrocoal, a product of American Methyl, sold under a waiver granted by the U.S. Environmental Protection Agency in 1981 that permitted up to 12 per cent methanol as long as the ratio of methanol to cosolvent was 6.5:1.

2. Du Pont was granted a similar waiver in mid-January 1985 provided that several important conditions related to concentration, co-solvents, corrosion inhibitors and volatility are met.]

However, these developments have not been unopposed and have met considerable resistance from car makers, some state air pollution control agencies, major oil companies and some consumers. Several states are currently considering legislation that will require strict labelling of blended fuels containing methanol and, to the extent that methanol poses a threat to the rapidly growing market for bulk ethanol as a gasoline component, that has already received strong support by way of tax concessions, there will be opposition from the agricultural section representing ethanol producers.

In Ontario a major study covering all aspects of methanol production and utilization as a liquid fuel has been underway since 1974 particularly in programs administered by the Ontario Ministry of Energy. Recent reviews of federal, state and municipal statutes has not indicated any major stumbling blocs in the way of introducing methanol. To the extent that federal statutes are involved, it would appear that a similar situation exists in NWT so that any inhibitory legislation, if it exists, will be found in local statutes.

Studies for the Ontario Government, made in 1978, concluded that methanol, like gasoline, is a toxic substance and that the standards which are applicable to gasoline will cover methanol. The Gasoline Handling Act and Code regulates fuel distribution, sets standards for containers, trucks and storage tanks and establishes fire fighting and safety requirements. The legislation also has machinery for adopting any standards the Canadian General Standards Board (CGSB) may set with regard to methanol based fuels. The present situation therefore seems much more progressive and flexible than in the United States.

Similar legislative machinery could be applied, to whatever extent may be necessary, by the Government of the Northwest Territories to regulate the use of methanol fuels.

Table 5.1
Physical Properties of Methanol

| | | |
|---|---|---|
| Molecular weight | 32.04 lb/lbmol | 32 gm/gmol |
| Melting Point | 179.1 K (-93.9°C) | -136.6°F |
| Boiling Point | 337.9 K (64.9°C) | +149.2°F |
| Density | 791.4 $kg.m^{-3}$ | 49.2 $lb.ft^{-3}$ |
| Index of Refraction | 1.3288 | 1.3288 |
| Heat of Formation | -7428 $J.g^{-1}$ | 3203 $BTU.lb^{-1}$ |
| *Heat of Combustion | -20100 $J.g^{-1}$ | 8658 $BTU.lb^{-1}$ |
| Heat Capacity | 2.55 $J.g^{-1}k^{-1}$ | 0.61 $BTU.lb^{-1}$ |
| Heat of Vapourization | 1172 $J.g^{-1}$ | 505 $BTU.lb^{-1}$ |
| Heat of Fusion | 99.14 $J.g^{-1}$ | 42.7 $BTU.lb^{-1}$ |
| Thermal Conductivity | 0.202 $J.s^{-1}.m^{-1}K^{-1}$ | $3.27x10^{-5}BTU.s^{-1}.ft^{-1}°F^{-1}$ |
| Critical Temperature | 512.4 K | 463.3°F |
| Critical Pressure | 79.2 atm | 1164.2 $lb.f/in.^2$ |
| Limits of Flammability vol% | 6.7-------36.0 | |
| Ignition Termperature in air | 658 K | 725.4°F |
| Surface Tension | $2.25x10^{-2}N.m^{-1}$ | 1.59 pdl/ft |
| Viscosity N-centipoise T-K | $N=9.3x10^{-3}$ exp(1250/T) | |

*to $CO_2(g)$ and $H_2O(g)$

## 5.2 Environment

The future introduction of methanol as a gasoline component, and the potential for impact on the environment, appears, to a large extent, to be covered by existing regulations governing the use of bulk gasoline fuel oils. A change from this situation could arise if methanol was to be used neat or as the preponderant component of new liquid fuels. In this case the differences between the physical and chemical properties of methanol compared with gasoline and fuel oils, their potential for harm to local ecosytems, would become of crucial importance. These differences would relate to impacts upon air and water qualities, land and animal systems and the immediate human environment.

As will be seen from the discussion in Section 4.1, consideration of the great majority of these factors is heavily weighted in favour of methanol. These may be summarized:-

a) methanol contains no sulphur
b) it burns with a cooler flame than petroleum oils, producing fewer nitrogen oxides, no polyaromatic hydrocarbons or particulates
c) it has much lower ignition and flammability hazards
d) is infinitely miscible with water
e) is rapidly biodegradable

Apart from human toxicity, where hazards are easily and conveniently controlled excepting, perhaps, deliberate abuse, methanol provides superior fuel characteristics.

It is expected that future environmental regulations considered necessary would be influenced by this preponderance of favourable factors.

# 6.0 ECONOMIC ANALYSIS OF METHANOL CONVERSION

## 6.1 Methodology for Calculating Netback Values

### Introduction

Stone & Webster has conducted a preliminary assessment of the economic viability of methanol use in NWT. The principal objective of this preliminary assessment is to estimate on an order of magnitude (O/M) basis the likely allocated cost of delivering methanol in the various communities, and an O/M estimation of deficits to be overcome. These deficits represent prospective differentials between revenues (e.g., community fuel bills with oil as the primary fuel) at projected oil prices* versus hypothetical revenues for a company distributing methanol at prices which cover allocated costs. Positive values for gas at the wellhead represent methanol systems which may be considered economic; negative netback values at the wellhead correspond to uneconomic configurations.

In section 6.2 the netback values are discussed relative to average oil prices on a heating value equivalent basis. Also, the allocated cost of methanol including production, transportation, and conversion costs is compared to oil prices on an equivalent heating value basis.

The imputed value of natural gas as a feedstock for methanol targeted for sale in the NWT as a liquid fuel is determined through its netback price at the wellhead. The netback price of gas is the market price of methanol minus the fully allocated costs of production, transportation, and any incremental consumption related costs such as equipment modification. The market price of methanol will at most equal to that of oil on a Btu equivalent basis. It must be assumed that on a consumption value basis, methanol costs the consumer no more than burning oil (furnace and diesel) on a Btu basis since methanol has approximately 49 per cent the equivalent heating value of a litre of diesel fuel or furnace oil, end users must burn over twice as much for a given energy requirement.

The potential quantity of methanol to be sold depends on its ability to displace oil in particular end-use applications. As described in Section 2, Stone & Webster's Competitive Fuels Model (CFM) was employed in the prior NWT study to measure the

*See Economic and Technical Feasibility Study of Distributing Natural Gas and/or Liquid to NWT Communities, Stone & Webster Canada Limited Exhibits 23 and 26, March 1984.

penetration potential of natural gas in each of the NWT communities evaluated. Methanol penetration discussed herein is based on prior research and has been adjusted substantially to comport with technical constraints.

In a methanol analysis a positive value indicates that all costs are covered, including payments to equity and bondholders. A negative netback results when costs are greater than revenues. For methanol production, a large percentage of the costs are fixed. This is due to the large initial capital outlay. A subsidy would be required for fixed cost reduction in unprofitable projects to lower annual capital related costs.

The financial analysis results are most sensitive to capital cost estimates. The large fixed cost component of total cost requires that the plant be run at a high rate of utilization to reduce the unit cost of production. In the base case the plant is assumed to operate at a 90 per cent capacity factor, or about 330 days. Netback values will vary dollar for dollar on an adjusted Btu basis with the price of oil. The oil price forecast therefore critically affects netback values, and thus the overall economic viability of substituting capital intensive methanol production technology for oil.

Not all benefits are fully captured in this analysis. This study evaluates methanol consumption on a project specific basis. The social benefits to NWT that could result from utilizing otherwise unmarketable gas in lieu of expensive petroleum products are not quantified. Thus the full economic benefits to NWT could be greater than those reported here.

The cost of the methanol plant is separated into fixed and variable costs components. In this study, all dollar flows are expressed in real (constant) dollar terms, and therefore omit general inflation. The fixed cost component includes the annualized capital costs and taxes. The annual level of fixed cost depends on the initial plant cost, the debt and equity proportions, and the cost of capital. Capital costs are defined as the annual payment necessary to recover the initial investment in plant and equipment plus interest. Debt and equity are treated separately to account for their different costs and tax treatment. The annual capital recovery factor used to compute the annualized cost is equal to $i(1+i)^n/[(1+i)^n-1]$ where i is the cost of capital and n the term of the project .

For both standard and non-standard technology, over time, these fixed costs decline in real (inflation adjusted) terms. Variable costs, including fuel and operating and maintenance expenses, increase each year due to inflation. In real terms they are assumed to remain constant.

## 6.2 O/M Economic Assessment Methanol Technology

Methanol production was evaluated for three communities: Yellowknife, Inuvik and a hypothetical remote community in NWT based on Tuktoyaktuk energy usage patterns. Each was examined under two different plant designs and standard technology and non-standard mini skid-mounted technology which has not been commercialized or demonstrated heretofore.

The standard technology is a 300 TPD plant costing $85 million. The non-standard technologies are represented by 30-35 TPD plant at an assumed cost of $5 million per plant.

The shadow price of gas or a netback price is computed for both standard and non-standard technology in each community as gas from Parsons Lake, Taglu, or Titalik. It is equal to the estimated market price of oil less the sum of plant cost, transportation costs and conversion costs for the end-user on a per unit basis. A revenue surplus or deficit is computed by project for each year. These values are then summed over the 15 year plant life on a discounted basis to yield the present value for a given project or supply configuration. A positive present value indicates that all costs including return on investment covered by revenues generated by the sale of methanol. A negative net present value is the size of the subsidy required to reach a break-even point. The results are summarized in Table 6.1 - 6.6.

Given the assumptions in Table 6.1, the first year fixed and variable cost are computed to be about $14.4 million and $4.9 million, respectively. For standard technology on a unitized basis, the fully allocated production cost in the first year is 15.7¢/litre, assuming a 90% plant utilization rate for a 300 tonne per day plant. This production related cost declines to about 11.5¢/litre in the tenth year. The market competitiveness of methanol also includes transportation and conversion cost components which substantially increase the retail price in each community.

The transportation cost component is based on work reported in the prior Stone & Webster NWT study. The values used for this report are repeated in Table 6.7.

TABLE 6.1

Yellowknife - Methanol Substitution Study (Standard Technology)
(Constant 1985$)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Component | | | | | | | | | | |
| Fixed Charges | $14,441,733 | $13,754,032 | $13,099,078 | $12,475,312 | $11,881,250 | $11,315,476 | $10,776,644 | $10,263,470 | $9,774,734 | $9,309,270 |
| O & M, inc. fuel | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 |
| Total | $19,341,733 | $18,654,032 | $17,999,078 | $17,375,312 | $16,781,250 | $16,215,476 | $15,676,644 | $15,163,470 | $14,674,734 | $14,209,270 |
| Annual Production (l) | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 |
| Yellowknife (l) | 41,267,679 | 41,281,750 | 41,302,153 | 41,322,556 | 41,342,959 | 41,363,362 | 41,383,765 | 41,410,500 | 41,437,235 | 41,463,970 |
| Allocated Cost of Plant | $6,464,530 | $6,236,807 | $6,020,804 | $5,815,021 | $5,618,979 | $5,432,216 | $5,254,297 | $5,085,581 | $4,924,844 | $4,771,711 |
| Sales (metric tons) | | | | | | | | | | |
| Residential | 11,459 | 11,560 | 11,666 | 11,772 | 11,878 | 11,983 | 12,089 | 12,200 | 12,311 | 12,422 |
| Commercial | 15,850 | 15,753 | 15,656 | 15,558 | 15,461 | 15,364 | 15,267 | 15,170 | 15,073 | 14,976 |
| Industrial | 1,623 | 1,631 | 1,638 | 1,646 | 1,653 | 1,661 | 1,668 | 1,676 | 1,683 | 1,691 |
| Power Plant | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 |
| | 32,856 | 32,868 | 32,884 | 32,900 | 32,916 | 32,933 | 32,949 | 32,970 | 32,991 | 33,013 |
| Sales (litres) | | | | | | | | | | |
| Residential | 14,392,606 | 14,519,246 | 14,652,217 | 14,785,189 | 14,918,161 | 15,051,133 | 15,184,104 | 15,323,408 | 15,462,712 | 15,602,015 |
| Commercial | 19,907,461 | 19,785,466 | 19,663,470 | 19,541,475 | 19,419,479 | 19,297,483 | 19,175,488 | 19,053,492 | 18,931,497 | 18,809,501 |
| Industrial | 2,038,990 | 2,048,417 | 2,057,844 | 2,067,271 | 2,076,698 | 2,086,125 | 2,095,551 | 2,104,978 | 2,114,405 | 2,123,832 |
| Power Plant | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 |
| | 41,267,679 | 41,281,750 | 41,302,153 | 41,322,556 | 41,342,959 | 41,363,362 | 41,383,765 | 41,410,500 | 41,437,235 | 41,463,970 |
| Transportation Cost ($/l) | $0.15 | $0.15 | $0.15 | $0.15 | $0.15 | $0.15 | $0.15 | $0.15 | $0.15 | $0.15 |
| Transportation Cost ($) | $6,190,152 | $6,192,262 | $6,195,323 | $6,198,383 | $6,201,444 | $6,204,504 | $6,207,565 | $6,211,575 | $6,215,585 | $6,219,596 |
| Annualized Conversion Cost | | | | | | | | | | |
| Residential | 421,248 | 401,189 | 382,085 | | | | | | | |
| Commercial | 28,569 | 27,209 | 25,913 | 24,679 | 23,504 | | | | | |
| Industrial | 85,708 | 81,625 | 77,739 | 74,037 | 70,512 | | | | | |
| Power Plant | 22,752 | 21,669 | 20,637 | 19,654 | 18,718 | | | | | |
| | 558,277 | 531,693 | 506,374 | 118,371 | 112,734 | | | | | |
| Estimated Oil Prices ($/l) | $0.391 | $0.407 | $0.407 | $0.416 | $0.423 | $0.431 | $0.437 | $0.445 | $0.452 | $0.455 |
| less Plant Cost ($/l) | $0.157 | $0.151 | $0.146 | $0.141 | $0.136 | $0.131 | $0.127 | $0.123 | $0.119 | $0.115 |
| less Trans. Cost ($/l) | $0.150 | $0.150 | $0.150 | $0.150 | $0.150 | $0.150 | $0.150 | $0.150 | $0.150 | $0.150 |
| less Conv. Cost ($/l) | $0.014 | $0.013 | $0.012 | $0.003 | $0.003 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Shadow Price of Gas ($/GJ) (cutback to wellhead) | ($7.783) | ($7.030) | ($6.701) | ($5.670) | ($5.217) | ($4.607) | ($4.212) | ($3.778) | ($3.380) | ($3.094) |
| Revenue (Deficit) | ($5,730,334) | ($5,231,953) | ($4,989,911) | ($4,224,291) | ($3,888,643) | ($3,436,020) | ($3,142,897) | ($2,820,427) | ($2,524,800) | ($2,312,898) |
| Present Value | ($30,227,825) | | | | | | | | | |

TABLE 6.2

Inuvik - Methanol Substitution Study (Standard Technology)
(Constant 1985$)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| **Cost Component** | | | | | | | | | | |
| Fixed Charges | $14,441,733 | $13,754,032 | $13,099,078 | $12,475,312 | $11,881,250 | $11,315,476 | $10,776,644 | $10,263,470 | $9,774,734 | $9,309,270 |
| O & M, inc. fuel | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 |
| Total | $19,341,733 | $18,654,032 | $17,999,078 | $17,375,312 | $16,781,250 | $16,215,476 | $15,676,644 | $15,163,470 | $14,674,734 | $14,209,270 |
| Annual Production (l) | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 |
| Inuvik (l) | 22,067,937 | 22,205,781 | 22,346,009 | 22,486,237 | 22,634,251 | 22,782,265 | 22,938,065 | 23,093,864 | 23,257,449 | 23,421,034 |
| Allocated Cost of Plant | $3,456,914 | $3,354,828 | $3,257,480 | $3,164,324 | $3,076,252 | $2,991,976 | $2,912,335 | $2,836,134 | $2,764,164 | $2,695,314 |
| **Sales (metric tons)** | | | | | | | | | | |
| Residential | 6,676 | 6,812 | 6,949 | 7,085 | 7,228 | 7,370 | 7,519 | 7,668 | 7,823 | 7,978 |
| Commercial | 5,563 | 5,532 | 5,501 | 5,470 | 5,439 | 5,408 | 5,377 | 5,347 | 5,316 | 5,285 |
| Industrial | 81 | 85 | 91 | 97 | 104 | 110 | 116 | 122 | 128 | 135 |
| Power Plant | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 |
| | 17,570 | 17,680 | 17,791 | 17,903 | 18,021 | 18,139 | 18,263 | 18,387 | 18,517 | 18,647 |
| **Sales (litres)** | | | | | | | | | | |
| Residential | 8,385,023 | 8,556,305 | 8,727,586 | 8,898,868 | 9,077,935 | 9,257,003 | 9,443,856 | 9,630,709 | 9,825,347 | 10,019,985 |
| Commercial | 6,987,029 | 6,948,203 | 6,909,386 | 6,870,570 | 6,831,753 | 6,792,936 | 6,754,119 | 6,715,302 | 6,676,486 | 6,637,669 |
| Industrial | 101,478 | 106,857 | 114,620 | 122,384 | 130,147 | 137,910 | 145,674 | 153,437 | 161,201 | 168,964 |
| Power Plant | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 |
| | 22,067,937 | 22,205,781 | 22,346,009 | 22,486,237 | 22,634,251 | 22,782,265 | 22,938,065 | 23,093,864 | 23,257,449 | 23,421,034 |
| Transportation Cost ($/l) | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 |
| Transportation Cost ($) | $2,317,133 | $2,331,607 | $2,346,331 | $2,361,055 | $2,376,596 | $2,392,138 | $2,408,497 | $2,424,856 | $2,442,032 | $2,459,209 |
| **Annualized Conversion Cost** | | | | | | | | | | |
| Residential | 199,597 | 190,093 | 181,041 | | | | | | | |
| Commercial | 10,027 | 9,550 | 9,095 | 8,662 | 8,249 | | | | | |
| Industrial | 30,081 | 28,649 | 27,285 | 25,985 | 24,748 | | | | | |
| Power Plant | 30,443 | 28,993 | 27,613 | 26,298 | 25,045 | | | | | |
| | 270,148 | 257,284 | 245,033 | 60,945 | 58,043 | | | | | |
| Estimated Oil Prices ($/l) | $0.401 | $0.413 | $0.424 | $0.432 | $0.441 | $0.448 | $0.457 | $0.464 | $0.472 | $0.480 |
| less Plant Cost ($/l) | $0.157 | $0.151 | $0.146 | $0.141 | $0.136 | $0.131 | $0.127 | $0.123 | $0.119 | $0.115 |
| less Trans. Cost ($/l) | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 |
| less Conv. Cost ($/l) | $0.012 | $0.012 | $0.011 | $0.003 | $0.003 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Shadow Price of Gas ($/GJ) (net back to wellhead) | ($4.960) | ($4.258) | ($3.700) | ($2.757) | ($2.253) | ($1.678) | ($1.206) | ($0.797) | ($0.373) | $0.030 |
| Revenue (Deficit) | ($1,973,545) | ($1,704,636) | ($1,490,478) | ($1,117,858) | ($919,307) | ($689,145) | ($498,792) | ($331,835) | ($156,539) | $12,532 |
| Present Value | ($7,425,508) | | | | | | | | | |

TABLE 6.3

Remote Community in NWT - Methanol Substitution Study (Standard Technology)
(Constant 1985$)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Component | | | | | | | | | | |
| Fixed Charges | $14,441,733 | $13,754,032 | $13,099,078 | $12,475,312 | $11,881,250 | $11,315,476 | $10,776,644 | $10,263,470 | $9,774,734 | $9,309,270 |
| O & M, inc. fuel | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 | $4,900,000 |
| Total | $19,341,733 | $18,654,032 | $17,999,078 | $17,375,312 | $16,781,250 | $16,215,476 | $15,676,644 | $15,163,470 | $14,674,734 | $14,209,270 |
| Annual Production (l) | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 |
| Tuktoyaktuk (l) | 3,185,748 | 3,210,480 | 3,235,212 | 3,243,308 | 3,251,404 | 3,259,500 | 3,267,596 | 3,275,692 | 3,283,788 | 3,291,885 |
| Allocated Cost of Plant | $499,043 | $485,036 | $471,612 | $456,407 | $441,903 | $428,067 | $414,871 | $402,284 | $390,281 | $378,833 |
| Sales (metric tons) | | | | | | | | | | |
| Residential | 1,086 | 1,113 | 1,139 | 1,152 | 1,166 | 1,179 | 1,192 | 1,205 | 1,219 | 1,232 |
| Commercial | 1,413 | 1,404 | 1,395 | 1,386 | 1,377 | 1,369 | 1,360 | 1,351 | 1,342 | 1,333 |
| Industrial | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 |
| Power Plant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2,536 | 2,556 | 2,576 | 2,582 | 2,589 | 2,595 | 2,602 | 2,608 | 2,614 | 2,621 |
| Sales (litres) | | | | | | | | | | |
| Residential | 1,364,132 | 1,397,404 | 1,430,675 | 1,447,311 | 1,463,947 | 1,480,583 | 1,497,219 | 1,513,854 | 1,530,490 | 1,547,126 |
| Commercial | 1,774,481 | 1,763,391 | 1,752,300 | 1,741,210 | 1,730,119 | 1,719,029 | 1,707,938 | 1,696,848 | 1,685,757 | 1,674,667 |
| Industrial | 47,135 | 49,685 | 52,236 | 54,787 | 57,338 | 59,889 | 62,440 | 64,990 | 67,541 | 70,092 |
| Power Plant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3,185,748 | 3,210,480 | 3,235,212 | 3,243,308 | 3,251,404 | 3,259,500 | 3,267,596 | 3,275,692 | 3,283,788 | 3,291,885 |
| Transportation Cost ($/l) | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 |
| Transportation Cost ($) | $334,504 | $337,100 | $339,697 | $340,547 | $341,397 | $342,248 | $343,098 | $343,948 | $344,798 | $345,648 |
| Annualized Conversion Cost | | | | | | | | | | |
| Residential | 30,394 | 28,946 | 27,568 | | | | | | | |
| Commercial | 1,523 | 1,450 | 1,381 | 1,315 | 1,253 | | | | | |
| Industrial | 4,568 | 4,351 | 4,144 | 3,946 | 3,758 | | | | | |
| Power Plant | 0 | 0 | 0 | 0 | 0 | | | | | |
| | 36,485 | 34,747 | 33,093 | 5,262 | 5,011 | | | | | |
| Estimated Oil Prices ($/l) | $0.501 | $0.519 | $0.530 | $0.540 | $0.551 | $0.560 | $0.571 | $0.580 | $0.590 | $0.600 |
| less Plant Cost ($/l) | $0.157 | $0.151 | $0.146 | $0.141 | $0.136 | $0.131 | $0.127 | $0.123 | $0.119 | $0.115 |
| less Trans. Cost ($/l) | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 |
| less Conv. Cost ($/l) | $0.011 | $0.011 | $0.010 | $0.002 | $0.002 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Shadow Price of Gas ($/GJ) (netback to wellhead) | ($2.359) | ($1.568) | ($0.954) | $0.059 | $0.617 | $1.180 | $1.709 | $2.163 | $2.637 | $3.102 |
| Revenue (Deficit) | (135,478) | (90,783) | (55,657) | 3,422 | 36,163 | 69,332 | 100,674 | 127,723 | 156,142 | 184,079 |
| Present Value | $179,972 | | | | | | | | | |

TABLE 6.4

Yellowknife - Methanol Substitution Study (Non-Standard Technology)
(Constant 1985$)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Component | | | | | | | | | | |
| Fixed Charges | $2,548,540 | $2,427,181 | $2,311,601 | $2,201,525 | $2,096,690 | $1,996,848 | $1,901,760 | $1,811,200 | $1,724,952 | $1,642,812 |
| O & M,inc. fuel | $848,664 | $848,664 | $848,664 | $848,664 | $848,664 | $848,664 | $848,664 | $848,664 | $848,664 | $848,664 |
| Total | $3,397,204 | $3,275,845 | $3,160,265 | $3,050,188 | $2,945,354 | $2,845,512 | $2,750,424 | $2,659,864 | $2,573,616 | $2,491,475 |
| Annual Production (1) | 46,626,471 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 |
| Yellowknife (1) | 41,267,679 | 41,281,750 | 41,302,153 | 41,322,556 | 41,342,959 | 41,363,362 | 41,383,765 | 41,410,500 | 41,437,235 | 41,463,970 |
| Allocated Cost of Plant | $3,006,762 | $1,095,249 | $1,057,128 | $1,020,811 | $986,213 | $953,252 | $921,852 | $892,075 | $863,706 | $836,679 |
| Sales (metric tons) | | | | | | | | | | |
| Residential | 11,459 | 11,560 | 11,666 | 11,772 | 11,878 | 11,983 | 12,089 | 12,200 | 12,311 | 12,422 |
| Commercial | 15,850 | 15,753 | 15,656 | 15,558 | 15,461 | 15,364 | 15,267 | 15,170 | 15,073 | 14,976 |
| Industrial | 1,623 | 1,631 | 1,638 | 1,646 | 1,653 | 1,661 | 1,668 | 1,676 | 1,683 | 1,691 |
| Power Plant | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 | 3,924 |
| | 32,856 | 32,868 | 32,884 | 32,900 | 32,916 | 32,933 | 32,949 | 32,970 | 32,991 | 33,013 |
| Sales (litres) | | | | | | | | | | |
| Residential | 14,392,606 | 14,519,246 | 14,652,217 | 14,785,189 | 14,918,161 | 15,051,133 | 15,184,104 | 15,323,408 | 15,462,712 | 15,602,015 |
| Commercial | 19,907,461 | 19,785,466 | 19,663,470 | 19,541,475 | 19,419,479 | 19,297,483 | 19,175,488 | 19,053,492 | 18,931,497 | 18,809,501 |
| Industrial | 2,038,990 | 2,048,417 | 2,057,844 | 2,067,271 | 2,076,698 | 2,086,125 | 2,095,551 | 2,104,978 | 2,114,405 | 2,123,832 |
| Power Plant | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 | 4,928,622 |
| | 41,267,679 | 41,281,750 | 41,302,153 | 41,322,556 | 41,342,959 | 41,363,362 | 41,383,765 | 41,410,500 | 41,437,235 | 41,463,970 |
| Transportation Cost($/l) | $0.10 | $0.10 | $0.10 | $0.10 | $0.10 | $0.10 | $0.10 | $0.10 | $0.10 | $0.10 |
| Transportation Cost($) | $4,085,500 | $4,006,893 | $4,088,913 | $4,090,933 | $4,092,953 | $4,094,973 | $4,096,993 | $4,099,640 | $4,102,286 | $4,104,933 |
| Annualized Conversion Cost | | | | | | | | | | |
| Residential | 421,248 | 401,189 | 382,085 | | | | | | | |
| Commercial | 28,569 | 27,209 | 25,913 | 24,679 | 23,504 | | | | | |
| Industrial | 85,708 | 81,626 | 77,739 | 74,037 | 70,512 | | | | | |
| Power Plant | 22,752 | 21,669 | 20,637 | 19,654 | 18,718 | | | | | |
| | 558,277 | 531,693 | 506,374 | 118,371 | 112,734 | | | | | |
| Estimated Oil Prices ($/l) | $0.391 | $0.407 | $0.407 | $0.416 | $0.423 | $0.431 | $0.437 | $0.445 | $0.452 | $0.455 |
| less Plant Cost ($/l) | $0.073 | $0.027 | $0.026 | $0.025 | $0.024 | $0.023 | $0.022 | $0.022 | $0.021 | $0.020 |
| less Trans. Cost($/l) | $0.099 | $0.099 | $0.099 | $0.099 | $0.099 | $0.099 | $0.099 | $0.099 | $0.099 | $0.099 |
| less Conv. Cost ($/l) | $0.014 | $0.013 | $0.012 | $0.003 | $0.003 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Shadow Price of Gas ($/Gj) (netback to wellhead) | ($0.307) | $2.707 | $2.793 | $3.594 | $3.827 | $4.227 | $4.423 | $4.668 | $4.885 | $4.999 |
| Revenue (Deficit) | (228,135) | 2,014,934 | 2,080,174 | 2,677,369 | 2,852,613 | 3,152,475 | 3,300,120 | 3,485,015 | 3,649,637 | 3,736,797 |
| Present Value | $18,976,968 | | | | | | | | | |

TABLE 6.5

Inuvik - Methanol Substitution Study (Non-Standard Technology)
(Constant 1985$)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Component | | | | | | | | | | |
| Fixed Charges | $1,699,027 | $1,618,121 | $1,541,067 | $1,467,683 | $1,397,793 | $1,331,232 | $1,267,840 | $1,207,467 | $1,149,968 | $1,095,208 |
| O & M,inc. fuel | $565,776 | $565,776 | $565,776 | $565,776 | $565,776 | $565,776 | $565,776 | $565,776 | $565,776 | $565,776 |
| Total | $2,264,803 | $2,183,897 | $2,106,843 | $2,033,459 | $1,963,569 | $1,897,008 | $1,833,616 | $1,773,242 | $1,715,744 | $1,660,984 |
| Annual Production (1) | 31,084,314 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 | 123,472,000 |
| Inuvik (1) | 22,067,937 | 22,205,781 | 22,346,009 | 22,486,237 | 22,634,251 | 22,782,265 | 22,938,065 | 23,093,864 | 23,257,449 | 23,421,034 |
| Allocated Cost of Plant | $1,607,869 | $392,762 | $381,297 | $370,326 | $359,951 | $350,024 | $340,641 | $331,662 | $323,181 | $315,067 |
| Sales (metric tons) | | | | | | | | | | |
| Residential | 6,676 | 6,812 | 6,949 | 7,085 | 7,228 | 7,370 | 7,519 | 7,668 | 7,823 | 7,978 |
| Commercial | 5,563 | 5,532 | 5,501 | 5,470 | 5,439 | 5,408 | 5,377 | 5,347 | 5,316 | 5,285 |
| Industrial | 81 | 85 | 91 | 97 | 104 | 110 | 116 | 122 | 128 | 135 |
| Power Plant | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 | 5,250 |
| | 17,570 | 17,680 | 17,791 | 17,903 | 18,021 | 18,139 | 18,263 | 18,387 | 18,517 | 18,647 |
| Sales (litres) | | | | | | | | | | |
| Residential | 8,385,023 | 8,556,305 | 8,727,586 | 8,898,868 | 9,077,935 | 9,257,003 | 9,443,856 | 9,630,709 | 9,825,347 | 10,019,985 |
| Commercial | 6,987,020 | 6,948,203 | 6,909,386 | 6,870,570 | 6,831,753 | 6,792,936 | 6,754,119 | 6,715,302 | 6,676,486 | 6,637,669 |
| Industrial | 101,478 | 106,857 | 114,620 | 122,384 | 130,147 | 137,910 | 145,674 | 153,437 | 161,201 | 168,964 |
| Power Plant | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 | 6,594,416 |
| | 22,067,937 | 22,205,781 | 22,346,009 | 22,486,237 | 22,634,251 | 22,782,265 | 22,938,065 | 23,093,864 | 23,257,449 | 23,421,034 |
| Transportation Cost($/l) | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 |
| Transportation Cost($) | $2,317,133 | $2,331,607 | $2,346,331 | $2,361,055 | $2,376,596 | $2,392,138 | $2,408,497 | $2,424,856 | $2,442,032 | $2,459,209 |
| Annualized Conversion Cost | | | | | | | | | | |
| Residential | 199,597 | 190,093 | 181,041 | | | | | | | |
| Commercial | 10,027 | 9,550 | 9,095 | 8,662 | 8,249 | | | | | |
| Industrial | 30,081 | 28,649 | 27,285 | 25,985 | 24,748 | | | | | |
| Power Plant | 30,443 | 28,993 | 27,613 | 26,298 | 25,045 | | | | | |
| | 270,148 | 257,284 | 245,033 | 60,945 | 58,043 | | | | | |
| Estimated Oil Prices ($/l) | $0.401 | $0.415 | $0.424 | $0.432 | $0.441 | $0.448 | $0.457 | $0.464 | $0.472 | $0.480 |
| less Plant Cost ($/l) | $0.073 | $0.018 | $0.017 | $0.016 | $0.016 | $0.015 | $0.015 | $0.014 | $0.014 | $0.013 |
| less Trans. Cost($/l) | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 |
| less Conv. Cost ($/l) | $0.012 | $0.012 | $0.011 | $0.003 | $0.003 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Shadow Price of Gas ($/Gj) (net back to wellhead) | ($0.313) | $3.141 | $3.439 | $4.134 | $4.404 | $4.754 | $5.012 | $5.218 | $5.448 | $5.667 |
| Revenue (Deficit) | ($124,500) | $1,257,430 | $1,385,705 | $1,676,140 | $1,796,994 | $1,952,808 | $2,072,902 | $2,172,636 | $2,284,444 | $2,392,779 |
| Present Value | $11,988,455 | | | | | | | | | |

TABLE 6.6

Remote Community in NWT - Methanol Substitution Study (Non-Standard Technology)
(Constant 1985$)

| | 1986 | 1987 | 1988 | 1989 | 1990 | 1991 | 1992 | 1993 | 1994 | 1995 |
|---|---|---|---|---|---|---|---|---|---|---|
| Cost Component | | | | | | | | | | |
| Fixed Charges | $849,513 | $809,060 | $770,534 | $733,842 | $698,897 | $665,616 | $633,920 | $603,733 | $574,984 | $547,604 |
| O & M,inc. fuel | $282,888 | $282,888 | $282,888 | $282,888 | $282,888 | $282,888 | $282,888 | $282,888 | $282,888 | $282,888 |
| Total | $1,132,401 | $1,091,948 | $1,053,422 | $1,016,729 | $981,785 | $948,504 | $916,808 | $886,621 | $857,872 | $830,492 |
| Annual Production (1) | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 | 15,542,157 |
| Tuktoyaktuk (1) | 3,185,748 | 3,210,480 | 3,235,212 | 3,243,308 | 3,251,404 | 3,259,500 | 3,267,596 | 3,275,692 | 3,283,788 | 3,291,885 |
| Allocated Cost of Plant | $232,114 | $225,559 | $219,277 | $212,169 | $205,388 | $198,920 | $192,750 | $186,866 | $181,253 | $175,901 |
| Sales (metric tons) | | | | | | | | | | |
| Residential | 1,086 | 1,113 | 1,139 | 1,152 | 1,166 | 1,179 | 1,192 | 1,205 | 1,219 | 1,232 |
| Commercial | 1,413 | 1,404 | 1,395 | 1,386 | 1,377 | 1,369 | 1,360 | 1,351 | 1,342 | 1,333 |
| Industrial | 38 | 40 | 42 | 44 | 46 | 48 | 50 | 52 | 54 | 56 |
| Power Plant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2,536 | 2,556 | 2,576 | 2,582 | 2,589 | 2,595 | 2,602 | 2,608 | 2,614 | 2,621 |
| Sales (litres) | | | | | | | | | | |
| Residential | 1,364,132 | 1,397,404 | 1,430,675 | 1,447,311 | 1,463,947 | 1,480,583 | 1,497,219 | 1,513,854 | 1,530,490 | 1,547,126 |
| Commercial | 1,774,481 | 1,763,391 | 1,752,300 | 1,741,210 | 1,730,119 | 1,719,029 | 1,707,938 | 1,696,848 | 1,685,757 | 1,674,667 |
| Industrial | 47,135 | 49,685 | 52,236 | 54,787 | 57,338 | 59,889 | 62,440 | 64,990 | 67,541 | 70,092 |
| Power Plant | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 3,185,748 | 3,210,480 | 3,235,212 | 3,243,308 | 3,251,404 | 3,259,500 | 3,267,596 | 3,275,692 | 3,283,788 | 3,291,885 |
| Transportation Cost($/l) | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 | $0.11 |
| Transportation Cost($) | $334,504 | $337,100 | $339,697 | $340,547 | $341,397 | $342,248 | $343,098 | $343,948 | $344,798 | $345,648 |
| Annualized Conversion Cost | | | | | | | | | | |
| Residential | 30,394 | 28,946 | 27,568 | | | | | | | |
| Commercial | 2,547 | 2,425 | 2,310 | 2,200 | 2,095 | | | | | |
| Industrial | 7,640 | 7,276 | 6,929 | 6,599 | 6,285 | | | | | |
| Power Plant | 0 | 0 | 0 | 0 | 0 | | | | | |
| | 40,580 | 38,647 | 36,807 | 8,799 | 8,380 | | | | | |
| Estimated Oil Prices ($/l) | $0.501 | $0.519 | $0.530 | $0.540 | $0.551 | $0.560 | $0.571 | $0.580 | $0.590 | $0.600 |
| less Plant Cost ($/l) | $0.073 | $0.070 | $0.068 | $0.065 | $0.063 | $0.061 | $0.059 | $0.057 | $0.055 | $0.053 |
| less Trans. Cost($/l) | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 | $0.105 |
| less Conv. Cost ($/l) | $0.013 | $0.012 | $0.011 | $0.003 | $0.003 | $0.000 | $0.000 | $0.000 | $0.000 | $0.000 |
| Shadow Price of Gas ($/Gj) (netback to wellhead) | $2.217 | $2.847 | $3.308 | $4.175 | $4.594 | $5.079 | $5.479 | $5.810 | $6.168 | $6.521 |
| Revenue (Deficit) | 127,357 | 164,794 | 192,963 | 244,122 | 269,309 | 298,480 | 322,795 | 343,141 | 365,169 | 387,011 |
| Present Value | $1,950,293 | | | | | | | | | |

Table 6.7

Estimated Transportation Costs

| To | From | Type | $/Litre |
|---|---|---|---|
| Inuvik | Titalik | Barge | $0.105 |
| Tuktoyaktuk | Titalik | Barge | $0.105 |
| Yellowknife | Zama Lake | Rail/Barge | $0.099 |

In order to burn methanol, some modification of the existing equipment will be required. For spacing heating in the residential, commercial and industrial sections, a cost of $500 per unit is needed to convert the heating equipment to burn methanol. In the power generating sector, $10,000 per diesel engine would be required to modify plants so that they can burn methanol equivalent to 40 per cent of current oil usage. Total unitized conversion costs in each community are relatively insignificant, ranging 1.4¢ to about 1.0¢ per litre of methanol. After conversion costs have been amortized or fully recouped, they have been eliminated from the economic assessment.

## 6.3 Methanol Export Potential

Depending on the cost of transporting methanol to southern Canadian markets, or potentially to the U.S. an export-oriented methanol plant based in NWT could potentially compete with Southern Canadian producers provided methane prices were less than fuel oil equivalence. However, there already exists abundant supplies of methanol at depressed market prices, and the short term increases of international supplies, particularly from the Middle East, will further destabilize what little price resistance has recently been seen. It therefore stands to reason that any prospective methanol development in NWT would be targeted exclusively for Territorial usages, no systematic evaluation of long term methanol export potential from limited on-shore reserves, or uncertain (abundant) offshore supplies of natural gas should be seriously considered at this time.

As shown in Table 6.8, retail methanol fuel prices for standard and non-standard technologies are substantially above average refined oil product prices after adjustments for heating value differentials. When the production-related costs are added to transportation and conversion costs, the allocated methanol price per litre is $.32 in Yellowknife, $.27 for remote communities in the first year. After adjustment for heat, the equivalent retail price on a volumetric basis is $.70 in

Yellowknife, $.60 for the Mackenzie Valley, and about the same retail price level for the remote communities. Thus, on an economic basis alone, retail methanol prices compare unfavourably to delivered oil prices, but could potentially be more attractive if oil prices escalate at a higher real rate than the 2.5 - 3.0 per cent average value incorporated in the prior study. A period of sustained real oil price escalation at 3 per cent or higher do not compare with today's realistic fuel price expectations.

Over the ten year horizon evaluated herein, the gap between methanol prices and oil prices lessens as oil tends to increase while methanol prices decline in real terms over time. This convergence is primarily a consequence of financial accounting, and does not reflect a fundamental revolution of methanol prices vis-a-vis oil product prices over time. In actuality, methanol prices would closely track changes in oil prices, the purpose of this analysis is merely to compare allocated retail prices with oil-driven market basing prices. Clearly, during the all-important initial three to five year period, methanol does not successfully compete against oil prices, and therefore does not achieve the required market saturations associated with the aforementioned forcast unless large external aid were procurable.

Given the large deficits to be overcome, the Government of NWT should not seriously contemplate methanol production using standard technology for petroleum product substitution. In Yellowknife, the O/M deficit to be overcome could exceed $30 million on a present value basis, and could be substantially higher if regional demand were significantly less than daily production capabilities. Moreover, if oil prices escalate at zero to 2 per cent per year in real terms over the course of the study period, the deficit to be overcome could approach $45 million.

For Inuvik and surrounding Mackenzie Delta communities including Native demand in Tuktoyakutuk, the estimated deficit on an O/M basis would likely approach approximately $7.5 million. For the remote communities, our analysis shows that methanol could potentially be economically feasible; this is because oil prices are already extremely high.

Methanol prices using the uncertain non-standard production technology do in fact compare favourably, or marginally to existing oil prices. As shown in Tables 6.4 to 6.6 and 6.8, the allocated costs of methanol are extremely close to average oil prices in the early critical years. Whereas, oil in Yellowknife is currently about $.40/litre, methanol produced in nearby fields like Cameron Hills or Zama could also be sold at the retail level at approximately $.40/litre. However, if the gas

from shut-in reserves in the Mackenzie Delta were utilized in lieu of local wells south of the Great Slave Lake, transportation charges would be 50 per cent higher or about $.15/litre. This would correspondingly increase retail prices and would result in significant annual deficits from year 1 to year 5, and insignificant deficits therefrom.

In Inuvik and the remote communities, non-standard technology yields retail prices which favourably compete with existing oil prices. Potential methanol delivery systems under these conditions would not generate substantial deficits.

TABLE 6.8

COMPARATIVE FUEL COSTS ON RETAIL BASIS (Constant 1985)

| Technology/Community | 1st Year (1986) | | | 10th Year (1995) | | |
|---|---|---|---|---|---|---|
| | Methanol | | Oil | Methanol | | Oil |
| | $/L | Oil Equiv. | $/Litre | $/L | Oil Equiv. | $/Litre |
| Standard | | | | | | |
| Yellowknife | .321 | .697 | .391 | .165 | .358 | .455 |
| Inuvik | .274 | .595 | .401 | . 22 | .477 | .480 |
| Remote | .273 | .592 | .501 | . 22 | .477 | .600 |
| Non-Standard | | | | | | |
| Yellowknife | .186 | .404 | .391 | .119 | .258 | .455 |
| Inuvik | .190 | .412 | .401 | .118 | .257 | .480 |
| Remote | .191 | .414 | .501 | .158 | .343 | .600 |

## 7.0 DEMONSTRATION SCHEMES

### 7.1 Methanol Production

7.1.1 Ideally a demonstration scheme would indicate that methanol could be manufactured on a small scale (community sized) locally, from natural gas at prices competitive with existing fuels and in an environmentally acceptable manner. Additional programs could then demonstrate that existing fuel supply networks could be modified and the methanol used for power generation and space heating without excessive cost as to render fuel substitution uneconomic.

7.1.2 The economic analysis provided in Section 6 shows that small scale methanol production by conventional standard technology will not be economically viable under current and projected fuel supply scenarios.

The economic analysis also shows that methanol production by non-standard mini-scale technology could be economically viable provided that the information available is reliable. However, careful examination of the vendor's information and a number of specific enquiries made during this study showed that insufficient design and engineering has been done by them to date to support technical plant specifications or reliable cost estimates. The mini-scale concepts remain unproven but cannot be ruled out.

7.1.3 Additional engineering studies to determine the feasibility of the mini-scale concepts are required but these expenditures are not justifiable as a demonstration program. In these circumstances the need for demonstrations of methanol as a substitute fuel are doubtful. However, should subsequent work show that miniscale production technologies are economically feasible the following programs would be needed on the utilization side.

### 7.2 Distribution and Storage

7.2.1 As the use of methanol as a substitute transportation fuel in NWT is not recommended, and as bulk methanol transportation is already an established business elsewhere in Canada, there is no real need to demonstrate this capability. The only uncertainties that would appear to require addressing are:

a) If Inuvik is the selected manufacturing centre, the existing fuel distribution network would have to be reversed between Inuvik and Fort Providence, i.e., fuel is currently transported by barge in the summer months down the Mackenzie River. Methanol would require barge transportation up the

Mackenzie. As methanol needs for the Central Arctic and the Inuvik area would be met from Inuvik, barge capacity should not be a critical limiting factor.

b) Current Barge movements up the Mackenzie would appear to be mainly in an unloaded condition. In future, the barges would be fully loaded, potentially increasing transit duration. This may require investigation given the short sailing season.

7.2.2 Existing tank materials used for fuel storage by the NCPC, commerce, institutions, and residences should be investigated for methanol compatibility. A survey of tank materials would indicate any materials or liners that are either unsuitable or unproven for methanol storage. Unproven materials or liners would require laboratory testing.

7.3 Methanol Utilization

7.3.1 Power Generation

7.3.1.1 Existing and experimental methods for the use of methanol in industrial diesel generators should be assessed further to select, say, the two most likely candidates for use in diesel generators in NWT. Currently the two most viable methods appear to be cetane improvement and dual fuel injection. One offers lower capital cost but higher operating (fuel) cost, the other offers higher capital cost and lower fuel cost. In view of the large range in unit sizes (30 kW to 5356 kW, average size approximately 600 kW) both solutions might be advisable, cetane improvers being used in the smaller units.

7.3.1.2 Inuvik and Aklavik would represent good locations for future field testing of diesels. Inuvik has four large diesels ranging from 2080 to 5356 kW in capacity. Aklavik, 60 km away, has three small units, the smallest being 298 kW. The close proximity of the two plants would lead to consistent operating practice and minimal supervisory effort.

7.3.1.3 Prior to the field test program which would primarily be aimed at ensuring operability and reliability in a realistic working environment, the co-operation and participation of diesel manufacturers in preliminary shop testing would be necessary.

7.3.1.4 Energy, Mines and Resources Canada (through its Transportation Energy Division) is the major funder of a program of field trials using neat methanol in large engines. The program will address bus and truck engines which, relative to stationary diesel generators, operate in a harsh environment. The program, begun April 1, 1985, is scheduled to finish in 1988. Additional support is being provided by other governments and the private sector.

7.3.1.5 It is recommended that any detailed diesel test program would encompass a literature research to ascertain what has already been done and proven viable or promising for further research. This will avoid duplication and possible waste of effort.

Detailed discussions with selected diesel manufacturers would then follow to ascertain the most effective test methods and objectives. The selected manufacturer(s) should then be awarded research contracts for the same. Typical research program figures given by a diesel manufacturer indicate that the cost would be $1 million and the duration would be one year.

7.3.2 Residential Heating

7.3.2.1 As the use of methanol in conventional warm air oil furnaces and warm air gas furnaces retrofitted with a condenser has already been proven, the purpose of a demonstration program would be to establish reliability and suitability of methanol in warm air oil fired domestic furnaces in NWT.

7.3.2.2 The proposed test program for residential warm air oil-heating would include the following:

a) Selection of a typical residence in NWT that has an outdoors storage tank, ideally one in the Inuvik area.

b) Conversion of the existing furnace and fuel handling system to one capable of handling and burning methanol. Modifications would include the installation of a car-rod sensor, similar to that used in gas burners, as conventional CdS flame detection devices do not work on methanol; equipping the fuel tank with a check valve and flame arrestor on the vent; installation of methanol resistant gaskets, seals, etc., if existing installation is not methanol compatible; installation of a methanol resistant fuel pump; installation of logging devices to record the number of hours and frequency of operation of the heating system.

c) The supply of methanol fuel to the residence so that the heating system can be run through an entire heating season.

d) The analysis of results from the above, in comparison with a neighbouring oil fired installation, and collection of the resident's comments on the system performance.

7.3.2.3 The proposed test program for space heaters would be similar to that described in Paper A-61 of the VI International Symposium on Alcohol Fuels Technology, titled "Thermal Efficiency and Emission Characteristics of Pot-type Methanol Burning Space Heater", by S. Tatsuta and K. Ito. A kerosene heater of a type

commonly used in NWT should be subjected to laboratory combustion tests. It is expected that this test would exhibit satisfactory operation using methanol without any changes being required to the heater. After successful laboratory testing, a one heating season test in a typical residence should be carried out, followed by dismantling and examination of the heater.

7.3.3 Commercial and Institutional Heating

7.3.3.1 Concurrent with the above, a suitable government institution could be selected for testing in a manner similar to that proposed for residential heating.

7.3.3.2 If hot water is the more common heating method for commercial and institutional heating the results obtained from the tests carried out in the Inuvik district heating plant (see 7.3.4) would suffice.

7.3.4 Hot Water District Heating

7.3.4.1 Inuvik uses a hot water district heating system with three hot water generators rated at 31.3 GJ, 65.6 GJ and 93.8 GJ per hour respectively. Winter peak load is approximately 83.4 GJ/h.

7.3.4.2 To keep costs down the smallest generator should be tested. Changes to the existing equipment would include the following:

a) Modification of the existing 31.3 GJ/h hot water generator to methanol firing capability. The modifications would include a new fuel handling system sized for methanol with a fuel forwarding system, a flow metering module, Buna-N gaskets and seals; new burners; new flame scanners; modified controls and instrumentation.

b) Changes to the boiler room to allow safe handling of methanol. Modifications would include increased ventilation; vapour and flame detectors; and explosion proof electrical components.

c) Modifications to the barge unloading system to ensure methanol compatibility.

d) It is estimated that these modifications would cost $100,000.

7.3.4.3 The proposed test program would have a duration of 30 days, requiring approximately 1,250,000 litres of methanol. Two barges, suitably modified for methanol handling, could be used for fuel storage for the duration of the test. Fuel transfer from the barges to the district heating plant would involve the full-time use of three road tankers, suitably modified for methanol.

7.3.4.4 The steam generator would require inspection before and after the 30 day test to see if any changes in its condition caused by methanol firing occurred.

7.3.4.5 All available instrumentation, possibly supplemented by additional instrumentation as necessary, should be used throughout the duration of the 30 day test to obtain all relevant operating data.

7.3.4.6 Upon completion of the test, all fuel handling equipment should be examined for possible methanol induced degradation and a combustion analysis performed.

## 8.0 CONCLUSIONS AND RECOMMENDATIONS

The principal findings are:

1. Small scale methanol production by existing standard technology is technically feasible in NWT. However, economic assessments conducted herein conclusively rule out application of downsized standard production technology because capital requirements would be excessively high and community conversion potential too inherently uncertain to justify large, risky capital expenditures.

2. Recently published claims for non-standard, mini-scale production of methanol in portable plants cannot be substantiated at this time. As of March 1985 no such plants have been built and no engineering designs upon which accurate capital cost estimates could be based are available. The available cost data is, therefore, conceptual and must be considered at this time extremely uncertain.

3. However, the technical feasibility of methanol systems offers, at least in theory, a practical alternative to continued reliance on refined petroleum products. If one accepts, for the moment, vendor claims of cost feasibility for the mini-scale plants, the economic analyses summarized in Table 6.8 portray favourable economic conditions. The sales forecasts for methanol in the three communities are realistically attainable given Government of NWT support for a pilot project or limited conversion program.

4. However, it is recommended that no pilot or demonstation projects should be seriously considered until adequate cost research yields reasonably precise capital and operating and maintenance cost estimates.

5. Consideration of methanol as partial or total substitution for existing fuels in heat and power generation has indicated no obvious technical constraints and the report discusses some appropriate demonstration programs.

6. The results of widespread trials of methanol as prime or supplementary blending fuel in motor gasolines, although promising, indicate that this form of substitution is not recommended for application in NWT at the present time.

7. Safety and health hazards and environmental factors resulting from methanol substitution have been investigated and again, appear to present no serious constraints.

8. A detailed review of existing legislation applicable in NWT should be performed before the general introduction of methanol as a fuel is permitted.

9. The prime recommendation is that additional research be focussed on developing a technical and economic data base for mini-sized (30-50 t/day), self-contained methanol plants in order to solidify capital and O&M estimates. This offers the best approach, at present, to the preponderance of shut-in natural gas in NWT and the formulation of lower cost alternatives to community energy cost burdens in the long run.

## APPENDIX 1

### 'MINI METHANOL REFINERIES' WOULD DRAW FROM SMALL GAS WELLS

A Texas independent oil and gas producer said he plans to market "little mini on-site methanol refineries," drawing from small natural gas wells, to help smaller independents to survive during "the current and future oil gluts." This, he said, "is the answer to the chicken before the egg question."

The unit will help smaller independents, those with one or more oil or natural gas wells, to "go directly to the market with methanol which can be sold in the neighborhood of 40¢ to 50¢ a gallon without tax incentives." He said this is the only real way for methanol to gain a foothold in the alcohol blend market. "There are too many studies indicating there is a huge methanol market if it's blended correctly.

"The methanol fuel business is where it's at. We've got more natural gas reserves (in the U.S.) than oil. Oil should be put into heavy industry where it's most needed, and not into polluting the air through vehicle exhaust emissions," he said.

The methanol plants, developed by Xytel Corp., Mt. Prospect, IL, would cost $2.6-million each, financed through loans based on existing reserves. The payback rate is predicted to be three years. The units would be sited on half-acre lots and are connected directly to the oil or natural gas well. "They use 1-million cu.ft. (of natural gas) a day to produce 9,000 gallons of methanol and 5,000 of natural gas liquids," he said. "The units are completely computer operated and take one person to monitor. The entire conversion process takes 10 hours from well to truck." The units are modular and are prefabricated. "We can get the cost to only $2.6-million per unit because we would be standardizing the mini methanol industry to 1-million cu.ft. a day, and would be using a fabricator to produce the various parts of the units. Then we would bring them back to our fabricating yard and assembly-line them together. The units would then be loaded onto skid mounts for final assembly at the natural gas or oil well."

The units are fed directly from the natural gas at the well. The natural gas is pumped from the well into a refrigeration unit, called a crygenic turbo expander. This freezes the liquid hydrocarbons down to methane and takes out all the ethanes. The methane is pumped into a distillation unit where it is turned into methanol. The methanol can be pumped directly into storage tank trucks which can take it directly to the market.

"It is simply a question of the smaller independents' being able to market their oxygenates since the majors dictate price and supply," he said. "Take your isolated wells in the Rockies where there are no

pipelines or trains. This unit is a way for these remote independents to take their natural gas, turn it into methanol, and get cash flow."

The source said he plans to have one "mini-refinery" built and in production in Oklahoma within the "next six months." He said he is currently finalizing the financing of the first unit, the prototype, which will cost $4- to $4.5-million to build.

"We're definitely going to go ahead with this project," he said. "I have signed letters of intent from United American Fuels who want to buy all the methanol we can produce plus an additional 200,000 gallons/day for sale to the pertrochemicals market." United American is the marketer of Petrocoal methanol-cosolvent blendstock.

Source: Alcohols Week - December 26, 1983, p. 11. Reprinted with permission of the publisher.

## APPENDIX 2

## METHYL ALCOHOL*

### Description:

$CH_3OH$, methyl alcohol, is a colorless, volatile liquid with a mild odor.

### Synonyms:

Methanol, carbinol, wood alcohol, wood spirit.

### Potential Occupational Exposures:

Methyl alcohol is used as a starting material in organic synthesis of chemicals such as formaldehyde, methacrylates, methyl amines, methyl halides, and ethylene glycol, and as an industrial solvent for inks, resins, adhesives, and dyes for straw hats. It is an ingredient in paint and varnish removers, cleaning and dewaxing preparations, spirit duplicating fluids, embalming fluids, antifreeze mixtures, and enamels and is used in the manufacture of photographic film, plastics, celluloid, textile soaps, wood stains, coated fabrics, shatterproof glass, paper coating, waterproofing formulations, artificial leather, and synthetic indiago and other dyes. It has also found use as an extractant in many processes, an antidetonant fuel-injection fluid for aircraft, a rubber accelerator, and a denaturant for ethyl alcohol.

A paritial list of occupations in which exposures may occur includes:

| | |
|---|---|
| Acetic acid makers | Ester makers |
| Art glass workers | Feather workers |
| Bookbinders | Felt hat makers |
| Bronzers | Foundry workers |
| Dryers | Gilders |
| Enamel makers | Ink makers |
| Lasters | Painters |
| Leather workers | Photoengravers |
| Millinery workers | |

NIOSH estimates that approximately 175,000 workers in the United States are potentially exposed to methyl alcohol.

*Hazardous and Toxic effects of Industrial Chemicals. Marshall Sittig (Editor), Noyes Data Corporation, Park Ridge, N.J., U.S.A., 1979, p. 296-297. Reprinted with permission of the publisher.

Permissible Exposure Limits:

The Federal standard is 200 ppm (260 $mg/m^3$). NIOSH recommends adherence to the present Federal standard of 200 ppm; 262 milligrams of methyl alcohol per cubic meter of air as a time-weighted average for up to a 10-hour workday, 40-hour workweek. In addition NIOSH recommends a ceiling of 800 ppm; 1,048 milligrams of methyl alcohol per cubic meter of air as determined by a sampling time of 15 minutes.

Routes of Entry:

Inhalation of vapor; percutaneous absorption of liquid.

Harmful Effects:

Local - Contact with liquid can produce defatting and a mild dermatitis. Methyl alcohol is virtually nonirritating to the eyes or upper respiratory tract below 2,000 ppm, and it is difficult to detect by odor at less than this level.

Systematic - Methyl alcohol may cause optic nerve damage and blindness. Its toxic effect is thought to be mediated through metabolic oxidation products, such as formaldehyde or formic acid, and may result in blurring of vision, pain in eyes, loss of central vision, or blindness. Other central nervous system effects result from narcosis and include headache, nausea, giddiness, and loss of consciousness. Formic acid may produce acidosis. These symptoms occur principally after oral ingestion and are very rare after inhalation.

Medical Surveillance:

Consider eye disease and visual acuity in any periodic or placement examinations, as well as skin and liver and kidney functions.

Special Tests:

Determination of methyl alcohol in blood, and methyl alcohol and formic acid in urine. Estimation of alkali reserve which may be impaired because of acidosis following accidental ingestion.

Personal Protective Methods:

Barrier creams and protective clothing.

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